SEWAGE AND INDUSTRIAL WASTES

(Formerly Sewage Works Journal)

JOURNAL of the FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATIONS

Special Features

Sludge Disposal by Dilution—Rawn and Bowerman

Effects of Sewage Irrigation—Steel and Berg

Pharmaceutical Wastes—Gallagher et al.

Shop and Foundry Wastes—Hathaway and Harvie

Sulfur Mine Wastes—Schwab et al.

Industrial Sewers—Ernest K. Smith

NOVEMBER, 1954—VOL. 26, No. 11

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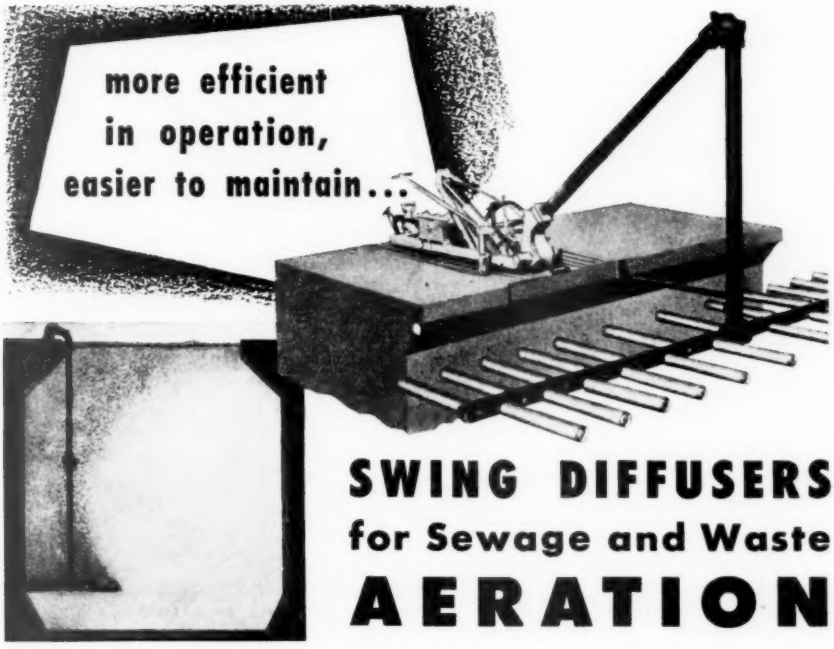

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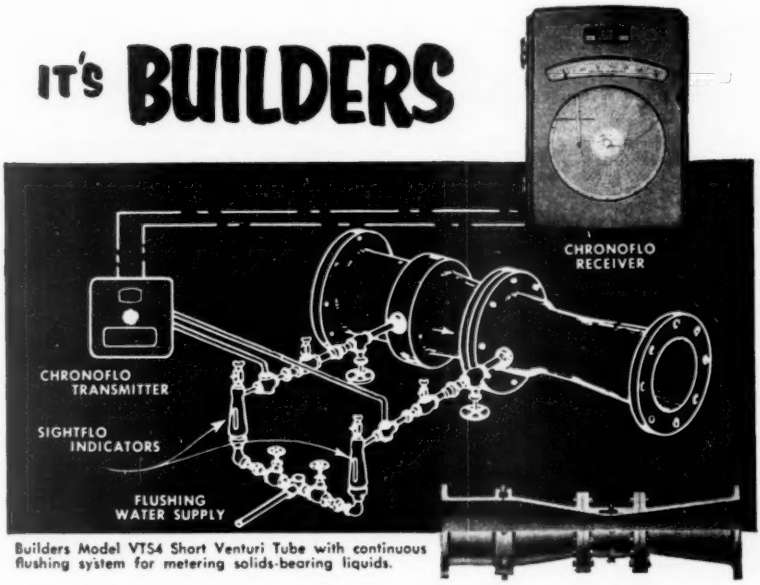

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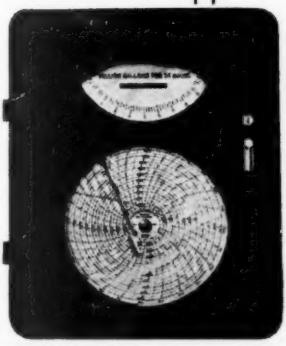

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MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
West Virginia Sewage and Industrial Wastes Assn.	Hotel Prichard, Huntington, West Va.	Nov. 9–10, 1954
Nebraska Sewage and Industrial Wastes Assn.	Keystone Hotel, McCook, Nebraska	Nov. 11–12, 1954
Oklahoma Water, Sewage and Industrial Wastes Conf.	Student Union Bldg., Stillwater, Okla.	Nov. 15–20, 1954
New York Sewage and Industrial Wastes Assn.	Hotel Belmont Plaza, New York, N. Y.	Jan. 20–21, 1955
Texas Water and Sewage Works Assn.	Texas A. and M. College, College Station, Texas	March 6–11, 1955
Arizona Sewage and Water Works Assn.	San Marcos Hotel, Chandler, Ariz.	April 14–16, 1955
California Sewage and Industrial Wastes Assn.	Mission Inn, Riverside, Calif.	April 27–30, 1955
Kentucky–Tennessee Industrial Wastes and Sewage Works Assn.	Phoenix Hotel Lexington, Ky.	Sept. 12–14, 1955

TWENTY-EIGHTH ANNUAL MEETING

Federation of Sewage and Industrial Wastes Associations

in conjunction with

New Jersey Sewage and Industrial Wastes Association

Ambassador Hotel, Atlantic City, New Jersey

October 10–13, 1955

Briefs from the YEOMANS GUARD

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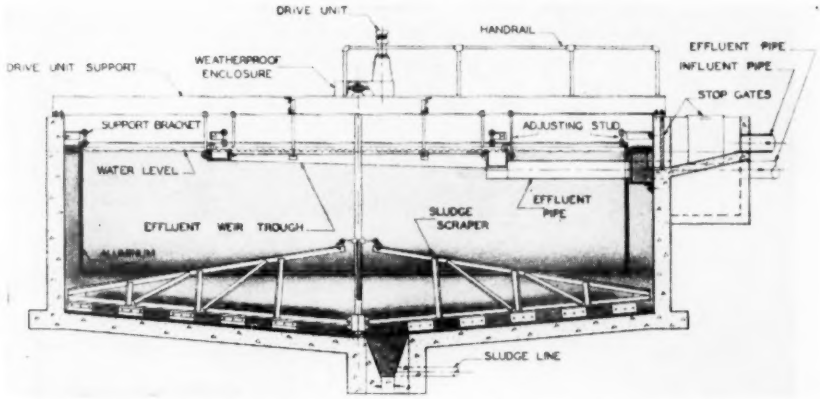

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FOR 100 YEARS

Photo: Ewing Galloway

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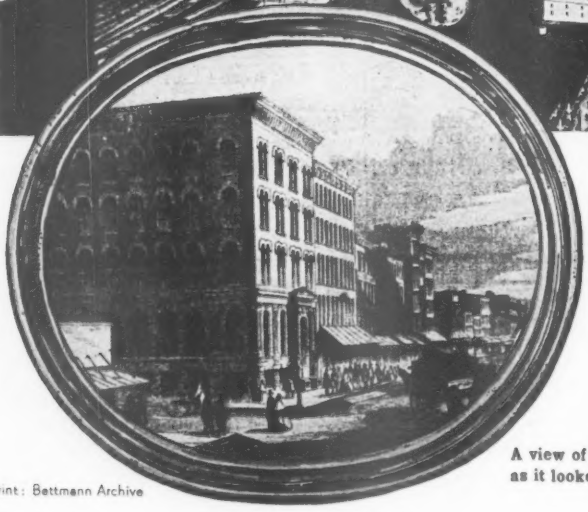

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A view of Lake Street, Chicago as it looked 100 years ago.

MODERNIZED **cast iron**

they've been coming back for more...

CHICAGO installed cast iron water mains 100 years ago... and installs them today!

Chicago's skyline has changed magically in a century but the underground lines that transport water are still cast iron. Nearly 100% of her water distribution system consists of cast iron pipe. This city of "magnificent distances" has over 4,000 miles (21 million feet) of cast iron mains, supplying more than one billion gallons of water per day to a population approaching four million.

A famous jurist defined *good will* as the "probability of the customer's returning to the old stand." Chicago's Water Department has been coming back for more cast iron pipe for 100 years. That's good will—yes—built on proved performance. Chicago has century-old cast iron pipe in its water distribution system.

Cast iron pipe has been a rugged, long-lived product from the earliest days. Today's *modernized* cast iron pipe, centrifugally cast, is even stronger, tougher, and more uniform in quality. And, where needed and specified, it is centrifugally lined with cement mortar to assure sustained carrying capacity throughout the long life of the pipe.

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Thos. F. Wolfe, Managing Director,
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Section of a century-old cast iron main still serving in Chicago's vast water distribution system.

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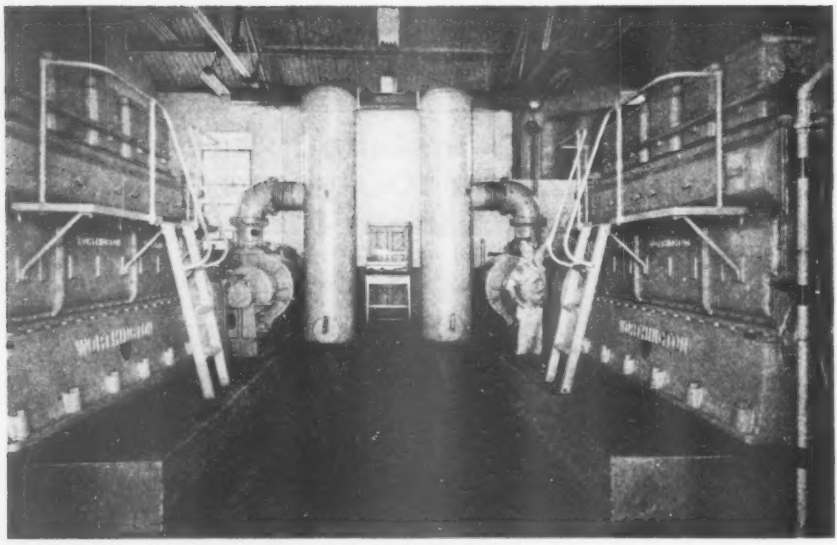
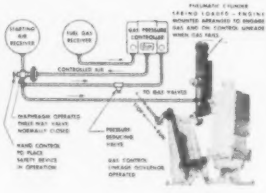
pipe FOR MODERN WATER WORKS OPERATION



ACTIVATED SLUDGE PLANT in Phoenix, Arizona gets low-cost power from these two Worthington dual-fuel engines which run on sewage gas, using a minimum amount of pilot oil.



WORTHINGTON'S NEW "AUTOMATIC FUEL SWITCHER" used on Worthington dual-fuel engines eliminates shutdowns due to fuel gas interruptions or failures. When gas pressure drops below normal, or fails completely, the Automatic Fuel Switcher instantly and automatically changes the engine over to 100% fuel oil.

The fuel switcher closes the gas metering valves instantly and simultaneously shifts linkages that place the fuel pumps under control of the governor at the required setting for the load at that moment. There is no hunting of the governor when the engine goes over to 100% fuel oil.

Sewage gas runs these engines

• In treating sewage, many cities have the help of a receiving stream to provide some purification of the liquid-borne wastes by the diluting action of the water.

Phoenix, Arizona, also has a receiving stream, the Salt River, but gets no beneficial diluting action since the entire flow of the Salt below Phoenix consists of effluent from the sewage treatment plant.

Naturally, a situation like this demands really thorough sewage treatment — and the best in equipment.

To supply the motive power for two large blowers, Phoenix's engineers selected two Worthington dual-fuel engines. And they put their sewage gas to work by using it as fuel for these dependable Worthington engines. You might say that this sewage plant is almost running itself.

Operating records of sewage treatment plants everywhere show that you just can't beat Worthington dual-fuel engines as economical, dependable drives for blowers, pumps and generators. Drop us a line and find out for yourself about Worthington's new "Automatic Fuel Switcher", which automatically changes over to 100% fuel oil when the gas pressure drops below normal.

Worthington Corporation, Engine Division, Section E.3.10, Buffalo, New York.

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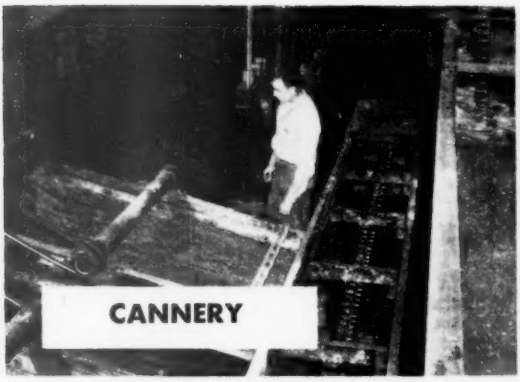
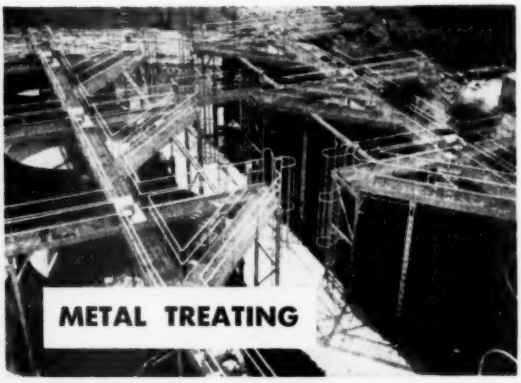


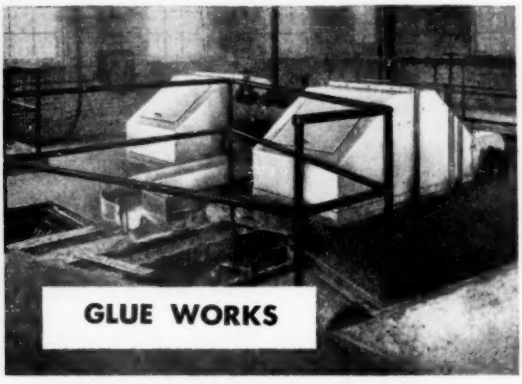
Link-Belt Thru-Clean Bar Screen, Straightline Grit Collector, flight conveyor and two liquid vibrating screens remove solids from waste water at midwest cannery.



Link-Belt flash mixers and thickener unit help separate toxic metals and cyanides from waste waters. Sludge thickening affords considerable savings in hauling costs.

or potential PROFITS...

Here profits were literally "going down the drain." But with Link-Belt Straightline Collectors installed, mill scale recovery rose from 250 to 475 tons per week.



Link-Belt Straightline Collector and Rotoline scum skimmer provide more efficient collection of solids, resulting in substantial reclaiming of grease and usable glue stock.

LINK-BELT knows how best to treat it

REGARDLESS of the nature of your waste . . . the size of your operations—Link-Belt experience and equipment assures a treatment system suited to your needs. If by-products are salvageable, Link-Belt can bring you maximum profits. Or if fast, low-cost waste treatment is the prime consideration, your answer lies in the job-proven efficiency of Link-Belt equipment. A call to your nearby Link-Belt office will put you in touch with a sanitary engineer. He's ready to work with your consultants and chemists—help you get the best in modern industrial liquids, water or sewage treatment equipment.

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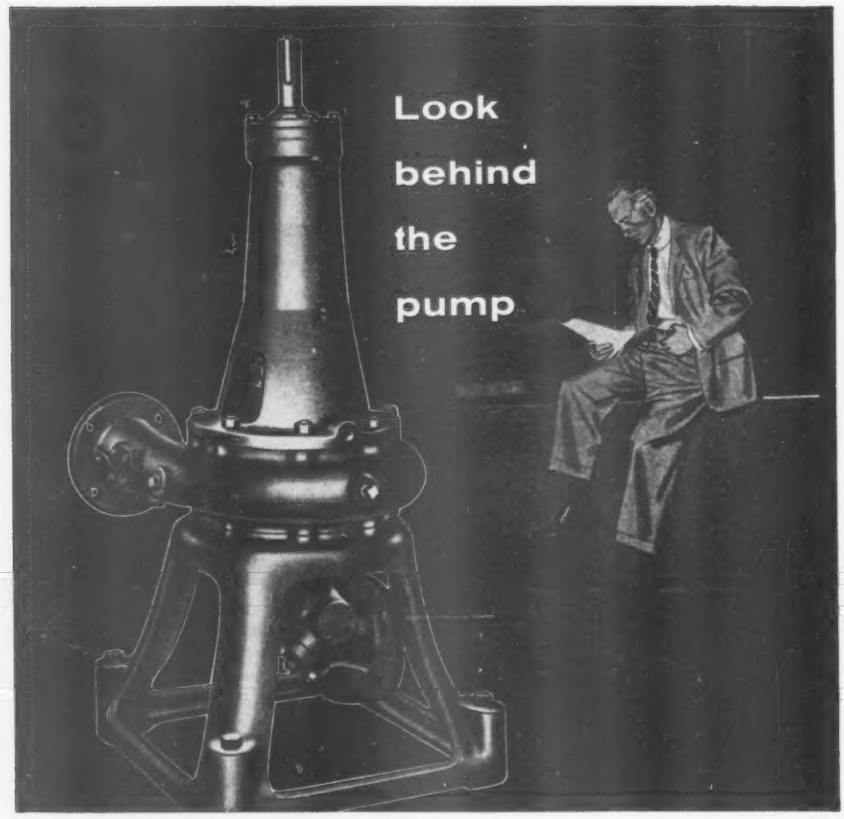


how much for maintenance?

In figuring the cost of a trash pump, what do you allow for maintenance . . . how much to clear out the trash that clogs the impeller? Will it be daily? Every other day? Weekly?

Or figure it this way. What price a pump that won't clog . . . that will virtually eliminate maintenance? That's why you should figure the Fairbanks-Morse Bladeless Impeller Pump! Its unique whirling tube won't clog . . . there are no blades or projections to catch and hold trash.

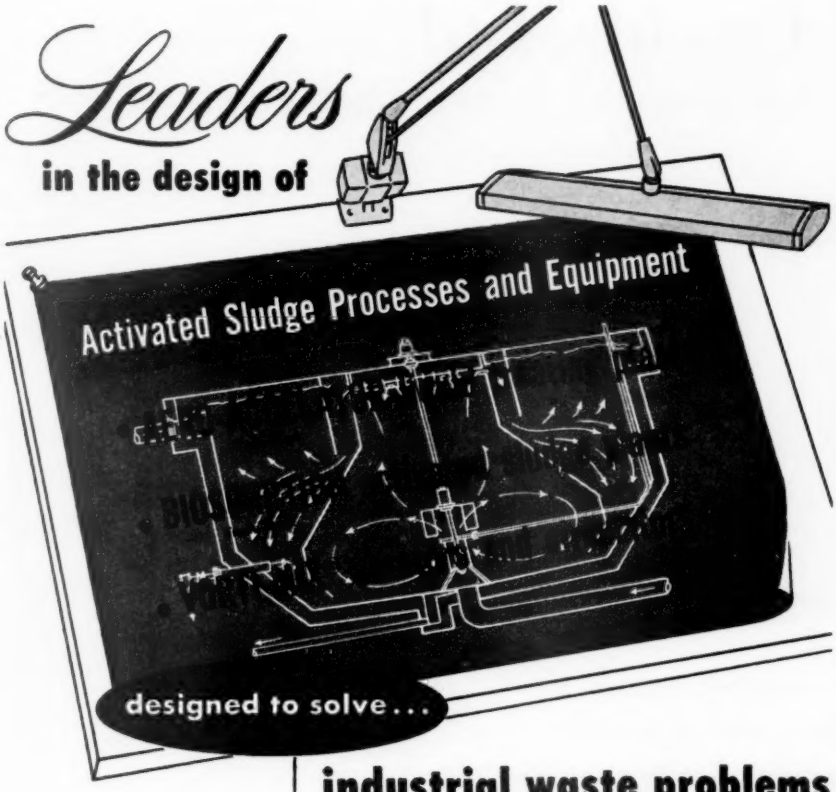
This is just one more example of the quality that is Fairbanks-Morse . . . in design, materials, workmanship, a standard of quality that gives you more for your pump dollar. For pump performance you can depend on, rely on the world's largest manufacturer of a complete pump line. See your Fairbanks-Morse Branch or write Fairbanks, Morse & Co., 600 S. Michigan Ave., Chicago 5, Illinois.

FAIRBANKS-MORSE

a name worth remembering when you want the best

PUMPS • SCALES • DIESEL LOCOMOTIVES AND ENGINES • ELECTRICAL MACHINERY
RAIL CARS • HOME WATER SERVICE EQUIPMENT • FARM MACHINERY • MAGNETOS

Leaders
in the design of



industrial waste problems

INFILCO's experience in solving industrial waste disposal problems through the application of activated sludge equipment is available to you today, at no obligation. Write for details.

BIOLOGICAL TREATMENT OF INDUSTRIAL WASTES with activated sludge is not new with INFILCO, an organization long considered a leader in the development of activated sludge processes and equipment.

Many installations treating vegetable canning, refinery, pulp, paper and a variety of other organic wastes, are in successful operation because INFILCO pioneered methods and equipment to adapt activated sludge treatment to the needs of industry's ever-increasing waste problem.

INFILCO

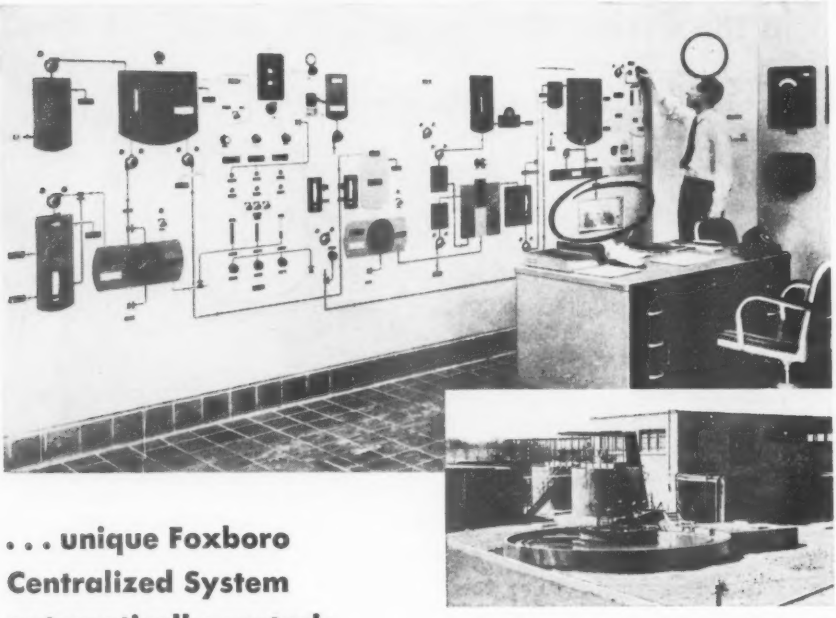
INFILCO INC. | *Tucson, Arizona*

Plants in Chicago and Joliet, Illinois

FIELD OFFICES IN 35 PRINCIPAL CITIES IN THE U. S., CANADA AND MEXICO

Oneida, Ltd.*

keeps waste quality "fit for a fishbowl"!



. . . unique Foxboro Centralized System automatically controls treatment — runs "sample" through aquarium!

Single operator at Foxboro Graphic Control Panel (above) directs combined batch and continuous processes in this ultra-modern waste treatment plant at Oneida, Ltd., Sherrill, N. Y. *Consulting Engineers: Westcott & Mapes, New Haven, Conn.*

There's living proof that modern treatment techniques under Foxboro Automatic Control keep plating waste completely safe for discharge at Oneida, Ltd., Sherrill, N. Y. Goldfish and plants flourish in an aquarium through which a sample of the treated waste flows!

This "fishbowl check" is the end-point on the Foxboro Graphic Panel which gives one operator complete control of the $1-million treatment plant. Foxboro Instrumentation automatically regulates such functions as flow, level, chlorine dosage, and oxidation tank transfer . . . makes 20,000 g.p.h. of complex wastes completely safe for aquatic life.

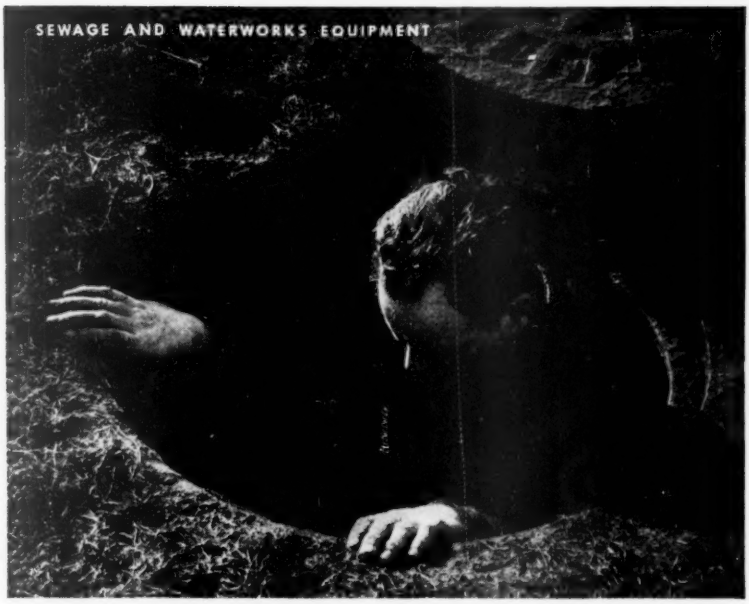
Foxboro Control Systems are continually solving similar waste problems . . . recovering by-products . . . building better public relations. Write for specific information. **The Foxboro Company, 8811 Neponset Ave., Foxboro, Mass., U. S. A.**

FACTORIES IN THE UNITED STATES, CANADA, AND ENGLAND

*Manufacturers of Community Silverplate and Heirloom Sterling

FOXBORO
Reg. U. S. Pat. Off.

Automatic Control for Waste Treatment



MANHOLE STEPS:

GIVE THEM AN EXTRA MARGIN OF SAFETY WITH CORROSION-RESISTANT EVERDUR

Manhole steps—of all sewage treatment and waterworks structures—need *extra* corrosion resistance and dependability. Everdur* gives it to them . . . and adds the strength that really pays off . . . in greater safety.

Everdur Copper-Silicon Alloys deliver the same corrosion resistance—*plus ease and economy of operation over the years*—to gates, screens, guides and bolts, weirs, float chambers, troughs, stems and electrical conduit. Everdur is easily fabricated into lightweight, built-up wrought-metal assemblies.

Depending on type or composition, Everdur Alloys can be worked hot or cold. You can form, forge, weld and machine them. They are available in the form of plates, sheets, rods, tubes, electrical conduit and casting ingots.

Write today for Anaconda's free booklet, "Everdur Copper-Silicon Alloys for Sewage Treatment and Waterworks Equipment." For specific help in selecting the right alloy for your equipment, consult our Technical Department. *The American Brass Company, Waterbury 20, Connecticut. In Canada: Anaconda American Brass Ltd., New Toronto, Ont.* 58140A

*Reg. U. S. Pat. Off.

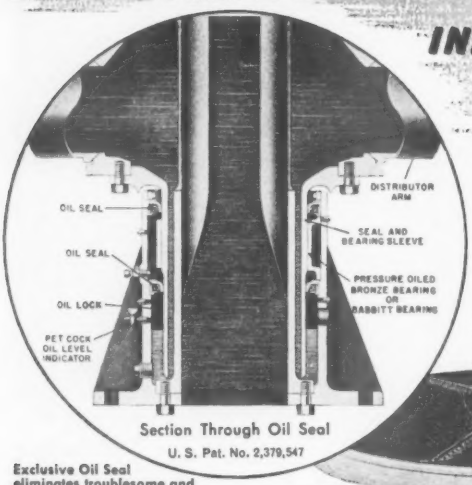
EVERDUR

ANACONDA®

COPPER-SILICON ALLOYS

STRONG • WELDABLE • WORKABLE
CORROSION-RESISTANT

American DESIGN FEATURES



Section Through Oil Seal

U. S. Pat. No. 2,379,547

Exclusive Oil Seal eliminates troublesome and costly mercury, completely protects bearing surfaces, and will not blow out under excessive heads.

INSURE

UNIFORM DISTRIBUTION

EFFICIENT CONTINUOUS OPERATION

MINIMUM MAINTENANCE

Reaction Drive and Positive Drive

ROTARY DISTRIBUTORS

Hundreds of installations have proved the advantages of *American* Rotary Distributors. This approval by consulting engineers is based on economy of initial cost, structural strength and durability, superior liquid distribution, applicability to wide ranges of flow and available head, and minimum maintenance. Inherent design features reduce hydraulic-head losses to a minimum, and provide for maximum utilization of available hydraulic head in performance of useful work. *Every oil seal unit installed has given excellent, trouble-free service!* Available in a wide range of both Reaction-Drive and Motor-Driven Positive-Drive Distributors to meet all variations of actual field conditions—for rapid or standard rate waste filters, sand filters, or for water aeration. *Utilize the experience of American engineers.*

For helpful data and design details, write for Technical Supplement RD

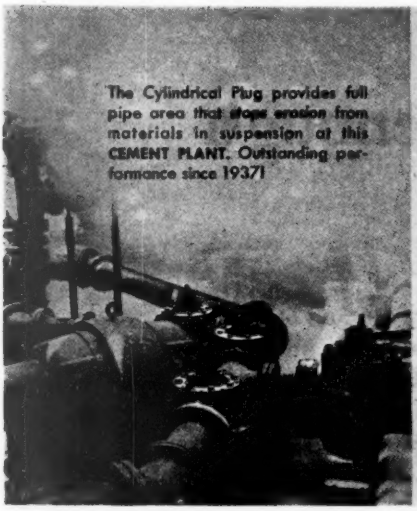
A Complete Line of Pumps and Process Equipment for Sewage and Industrial Waste Treatment.

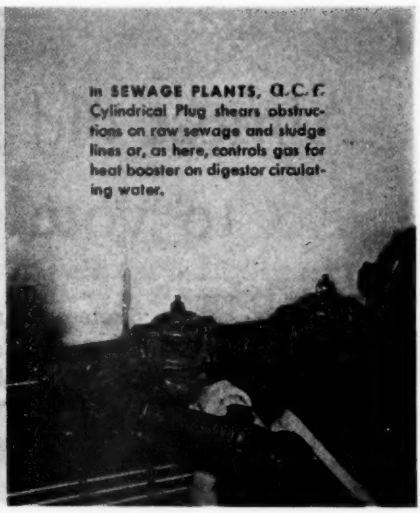
AMERICAN WELL WORKS

IN OUR 86th YEAR
110 North Broadway
AURORA, ILLINOIS

Pumping, Sewage Treatment, and Water Purification Equipment
RESEARCH · ENGINEERING · MANUFACTURING

Offices: Chicago · New York · Cleveland · Cincinnati · Kansas City · Sales Representatives throughout the World


The Cylindrical Plug provides full pipe area that stops erosion from materials in suspension at this CEMENT PLANT. Outstanding performance since 1937!

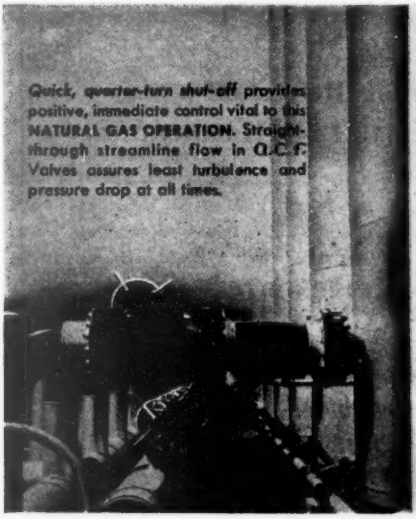

In SEWAGE PLANTS, A.C.F. Cylindrical Plug shears obstructions on raw sewage and sludge lines or, as here, controls gas for heat booster on digestor circulating water.

PROOF OF SUPERIORITY

acf CYLINDRICAL FULL PIPE AREA **PLUG VALVES**

Representatives in 50 Principal Cities

Write for descriptive Catalog 4-SI to A C F Industries, Incorporated, Valve Division, 1501 E. Ferry Avenue, Detroit 11, Michigan.


Quick, quarter-turn shut-off provides positive, immediate control vital to this NATURAL GAS OPERATION. Straight-through streamline flow in A.C.F. Valves assures least turbulence and pressure drop at all times.

In PROCESSING PLANTS, A.C.F. Valves provide dependable control of fluids in steady performance in this vital operation for 5 years. Now you get new dependability with TEFLON* HEAD GASKETS.

Almost old enough to vote!

Nineteen years old and still going strong! The oldest of all sludge incineration methods—the original Dearborn, Michigan, installation, has provided thousands of hours of faithful, trouble-free, odor-free sludge incineration with Nichols Herreshoff furnaces.

Dozens of municipalities all over the country are finding Nichols Herreshoff Dryer-Incinerators to be a good investment. No other method of sludge incineration provides such rugged equipment, such dependable service, such low cost disposal.

If you want to burn all solids—grit included, with the least trouble . . . consult Nichols.

Nichols Herreshoff
Multiple Hearth Dryer-Incinerators

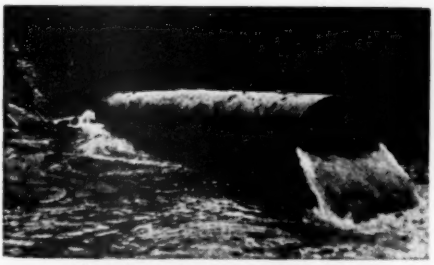
Nichols Engineering & Research Corp.
70 Pine St., New York 5, N. Y.
1637 N. Illinois St., Indianapolis 2, Ind.
40 S. Los Robles Ave., Pasadena 1, Calif.
1477 Sherbrooke St. W., Montreal 25, Canada

Which Armco Sewer Saved the Most Money?

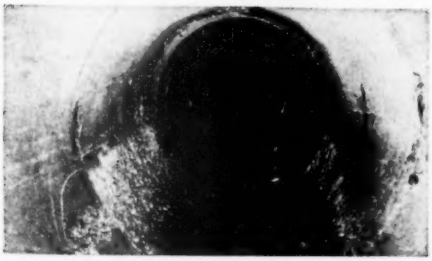
Fact is, they *all* saved plenty of money. But the original Armco Sewer will save much more through the years.

The Armco Pipe will be faced with the same hazards that were disastrous to the other structures. But because of the flexible strength of corrugated metal, there is no danger of cracking. Positive bolted connections eliminate disjointing. And with Armco ASBESTOS-BONDED Pipe, corrosive sewage will not cause damage. A long life for the new Armco Sewer is assured.

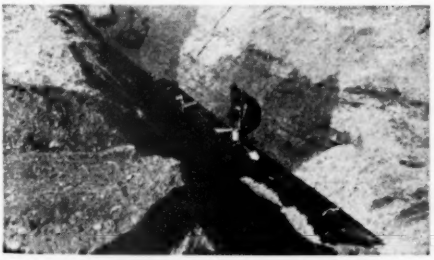
There is an Armco Structure to solve practically every sewer problem. Armco Corrugated Metal Pipe and Pipe-Arch are recommended for normal sewer use; ASBESTOS-BONDED Pipe and Pipe-Arch for severe corrosion problems; MULTI-PLATE Pipe, Arch and Pipe-Arch for large area requirements. Write us for data. Armco Drainage & Metal Products, Inc., 3134 Curtis Street, Middletown, Ohio. Subsidiary of Armco Steel Corporation.



Threading cracked sewer in Georgia



Lining failing sewer in Wisconsin



Installing new Armco Sewer in Ohio

Replacing disjointed sewer in California

ARMCO SEWER STRUCTURES

ARMCO

HOW LARGE
IS YOUR COMMUNITY?

C-E RAYMOND SEWAGE DISPOSAL SYSTEMS SERVE BOTH LARGE AND SMALL

IN BALTIMORE, FOR EXAMPLE — the new sludge drying plant was placed in service late last year. Serving nearly a million people, the new installation is designed to dry the sludge from 125 million gallons of sewage a day.

An important part of the huge Back River Treatment Works, the plant was designed by Whitman, Requardt & Associates, Baltimore.

Three C-E Raymond Flash Drying Systems dry the digested filtered sludge, to produce 15,000 to 27,000 tons of fertilizer a year.

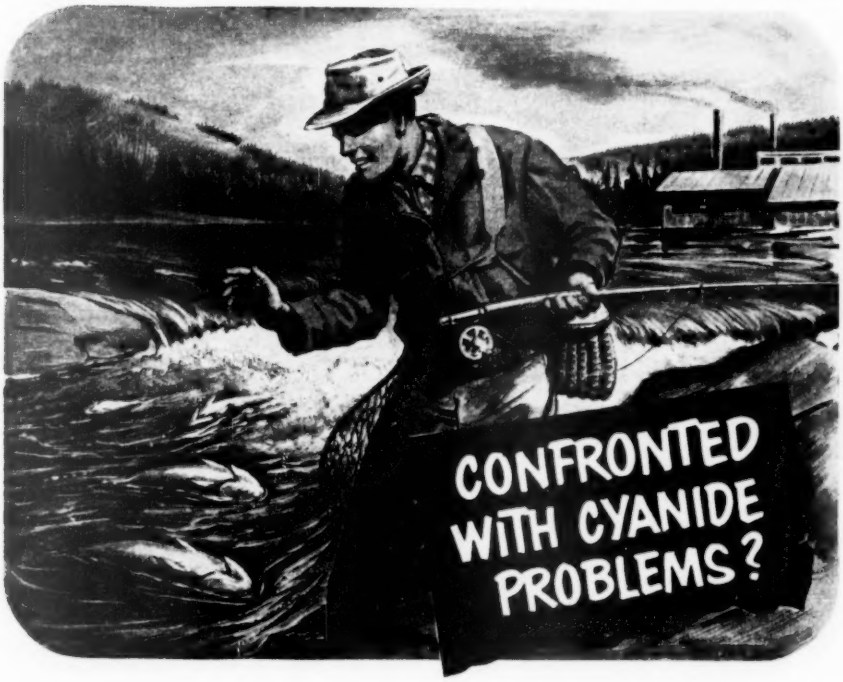
Many other large communities have discovered the practical answer to sludge disposal problems in C-E Raymond Systems. Chicago . . . Los Angeles . . . San Francisco . . . Washington — these cities alone have in operation or under construction C-E Raymond equipment to serve an equivalent population greater than 11,000,000.

And in communities with equivalent populations as low as 6,000, it has been proved in years of actual service. The aggregate capacity of C-E Raymond Systems installed, under construction or on order is *nearly 50% more than the total of all other heat methods combined.*

So look to the leader for the most efficient end to your sludge disposal problems. Get in touch with the C-E Raymond office nearest you. B-717A

COMBUSTION ENGINEERING

RAYMOND DIVISION: 1315 North Branch Street, Chicago 22, Illinois
Western Office: 510 W. Sixth St., Los Angeles 14, Cal. • Eastern Office: 200 Madison Ave., N. Y. 16, N. Y.
ALSO FLASH DRYING AND INCINERATION SYSTEMS FOR INDUSTRIAL WASTE DISPOSAL



Make use of the Unique Advantages of WELSBACH OZONE in Solving Them

The disposal of industrial wastes containing cyanide compounds is always a problem—because they are difficult to treat and must be reduced to very low limits.

That's why you should investigate the potential of Welsbach Ozone in solving these problems. Its efficiency, its economy and above all, its dependability provide an immediate answer. Investigations in the field, as well as laboratory research show that Welsbach Ozone is the ideal solution.

JUST CONSIDER THESE ADVANTAGES:

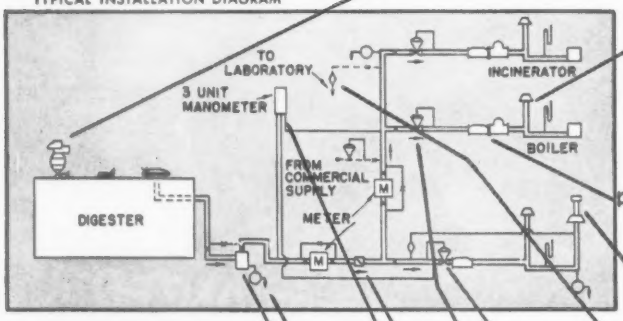
1. Cyanides are readily oxidized by ozone to products of negligible toxicity.
2. Overdoses of ozone can *not* result in toxic residuals in the treated waste. Therefore, close technical control over dosage is unnecessary and regular maintenance employees can operate the waste treatment plant.
3. Since ozone adds nothing but oxygen to the reaction, re-use or re-cycling of waste waters are often possible, resulting in substantial savings in volume of water used and in waste treatment cost.
4. A Welsbach Ozone plant can be operated on a batch or a continuous basis and can be made fully automatic. Ozonators and treatment vessels require very little space.
5. Welsbach Ozone is generated where it is used. No procurement problems. No freight, storage or materials handling expense.
6. Maintenance costs are negligible. And since the only raw materials needed are electricity and air or oxygen, operating costs are constant and predictable.

. . . but, most of all Welsbach Ozone is economical, convenient and dependable. Write today for information and, if you wish, indicate the nature of your problem. The Welsbach Corporation, Ozone Processes Division, 1500 Walnut Street, Philadelphia 2, Pa.

Investigate **WELSBACH OZONE**

LOW COST • DEPENDABLE

TYPICAL INSTALLATION DIAGRAM



"VAREC" Pressure Relief and Vacuum Breaker Valve with Flame Arrester — Fig. 5800C — Relieves excess pressures and vacuum in digesters and protects vessels from outside fires.

"VAREC" Explosion Relief Valve—Fig. 70—Relieves sudden surges in pressure from explosion or momentary plant fluctuations.

"VAREC" Flame Trap Assembly—Fig. 450—Prevents flame propagation in piping.

"VAREC" Waste Gas Burner—Fig. 236, 237 or 238—Efficiently burns all excess gas.

"VAREC" Flame Check—Fig. 51A or 52A—Prevents flashback from burner pilot or laboratory burners.

"VAREC" Pressure Relief and Flame Trap Assembly—Fig. 440—Permits excess pressure to be wasted through gas burner and prevents flame flashback from burner.

"VAREC" Pressure Reducing Regulator—Fig. 187 —Controls pressure of gas going to utilization equipment.

"VAREC" Check Valve—Fig. 211 or 211A—Controls direction of gas flow.

"VAREC" Manometer—Fig. 215, 215A, 216 or 216A—Indicates system pressures.

"VAREC" Drip Trap—Fig. 245 or 248.

"VAREC" Sediment Trap — Fig. 230, 232 or 233 — Keeps lines drained and free from moisture.

Plan with "Varec" Symbols of Safety

FOR GAS CONTROL THROUGHOUT YOUR SEWAGE TREATMENT PLANT

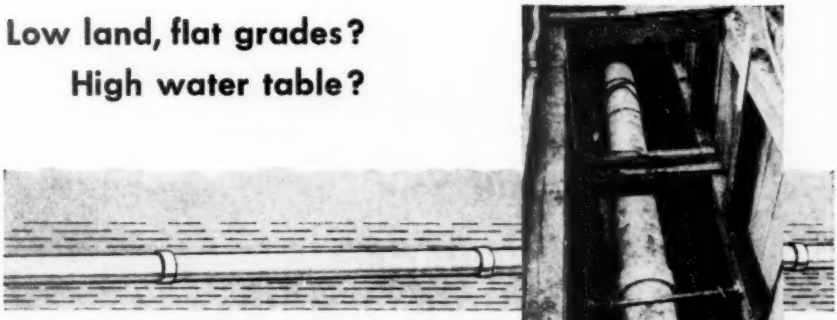
"Varec"

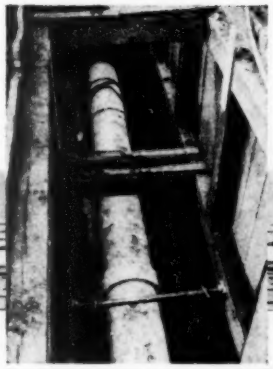
THE VAPOR RECOVERY SYSTEMS COMPANY

COMPTON, CALIFORNIA, U. S. A.

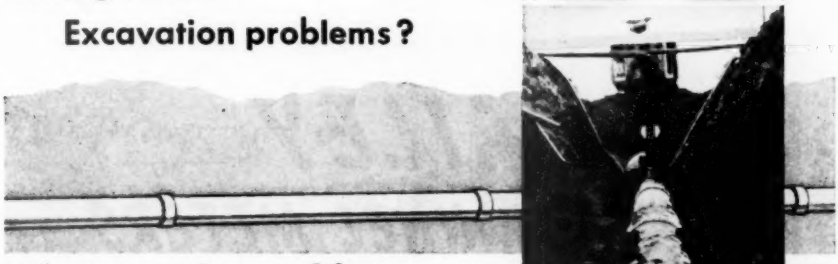
S-10 *Available from Authorized Sewage Equipment Agents throughout U. S. and Canada.*

Low land, flat grades?
High water table?





Rolling land?
Excavation problems?



Whatever the problem—

Transite® Sewer Pipe

speeds installation, cuts operating costs

In a wide range of conditions, Transite Sewer Pipe and its Ring-Tite® Coupling provide installation and operational *plus-advantages* that add up to important cost savings.

[**Flow Coefficient n=0.010**] For instance, with Transite Sewer Pipe, specified velocity of flow can be attained at a minimum grade. Initial savings may also be reflected in smaller pipe sizes. Its unusually low flow coefficient (n=0.010 derived from the Manning formula) makes this possible. This means less cubic yards of excavation, and may also mean . . . elimination of pumping . . . location of treatment plant at higher elevation . . . lower installation costs especially if in wet or ground-water conditions.

[**Tight Joints**] Where ground water conditions exist (due to a constant water table or during seasonal rains) Transite's Ring-Tite Couplings are *tight* . . . thus treatment-plant dollars are spent to treat *normal* sewage only, not excessive and unnecessary infiltration.

[**Strength**] Made of asbestos and cement, Transite Sewer Pipe is strong and durable. It withstands heavy load stresses, eliminates expensive cradling in many cases. It is available in two strength classifications.

Transite Sewer Pipe is easily handled, quickly assembled and lowered into trench where it adjusts more accurately to line and grade. The Ring-Tite Couplings are easily and quickly pulled, forming tight, flexible joints that *start* tight and *stay* tight.

For your copy of TR-94A, the helpful widely used Sewer Design Flow Chart, based on the Manning formula, write Johns-Manville, Box 60, New York 16, N. Y.

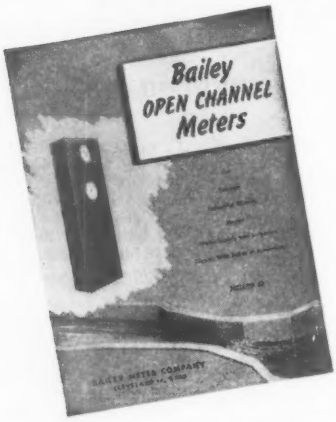
Johns-Manville TRANSITE SEWER PIPE

THE PIPE WITH THE TIGHT JOINTS

For trouble-free, low cost measurement of—

SEWAGE
INDUSTRIAL WASTES
SLUDGE
IRRIGATION WATER

BAILEY
OPEN CHANNEL METERS
Offer These Advantages:



1. Easy to Install
2. Retain Accuracy
3. Self-Cleaning
4. Adjustable Capacities
5. Totalize Multiple Flows
6. Chemical Feed Control
7. Flow and Ratio Controls

Ask for Bulletin 62

MU22

BAILEY METER COMPANY

1066 IVANHOE ROAD • CLEVELAND 10, OHIO

METERS and CONTROLS for SEWAGE and WATER

VENTURI TUBES, FLUMES, WEIRS, NOZZLES, ORIFICES • DIRECT MECHANICAL AND REMOTELY LOCATED REGISTERS • AIR-OPERATED, ELECTRONIC AND ELECTRIC CONTROLS.

The Disappearing Act that never fails

A billion-mile network of buried faith lies stretched across America. It's Vitrified Clay Pipe — the product that disappears underground . . . and *has* to be trusted. Clay Pipe is sealed in by streets and sidewalks . . . blocked off by building foundations . . . piled over with earth and rock.

Yet — nobody worries about that vast network of sanitary protection. Few people even think about it. What greater tribute could be paid to a product's dependability?

You *know* Clay Pipe is good — not only because of its magnificent record in the ground, but because it is guaranteed for 50 years. It's the only pipe that *never wears out*, and the Clay Pipe Industry is mighty proud of it.

Vitrified

CLAY PIPE

NEVER WEARS OUT!

NATIONAL CLAY PIPE MANUFACTURERS, INC.
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C-354-SA

NEW

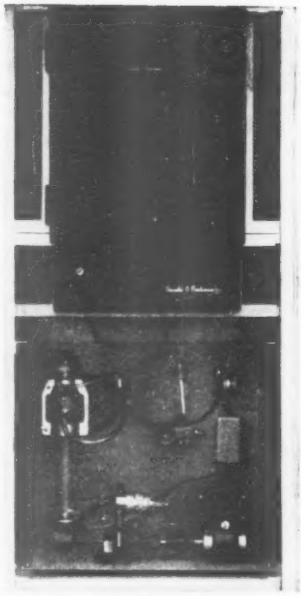
Arnold O. Beckman

DISSOLVED OXYGEN ANALYZER

for continuous measurement!

The accurate measurement of dissolved oxygen in fluid process streams is widely recognized as an important control factor in such municipal and industrial operations as sewage and water treatment . . . waste disposal . . . petro-chemical and chemical processes . . . food processes . . . and many others.

Now, you can make such measurements—continuously, simply and accurately—with the newly-developed Arnold O. Beckman Model 1A3B Dissolved Oxygen Analyzer!



The Model 1A3B is a complete, compact unit—with the Analyzer in top compartment and the scrubbing unit below.

Continuous record

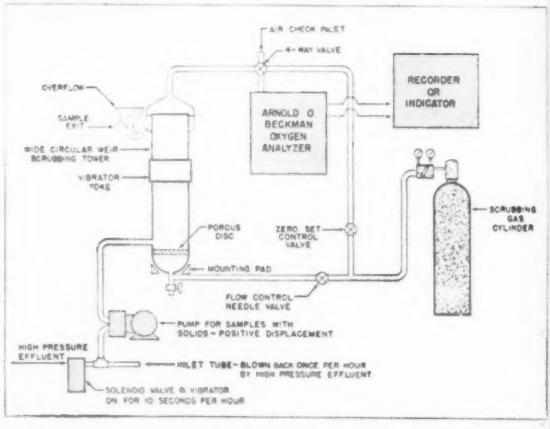
Handles fluids, slurries, sludges, etc.

Simple operation

Highly accurate

- **The new Model 1A3B combines the field-proven Arnold O. Beckman paramagnetic principle of oxygen measurement with an improved method of stripping to provide a measurement specific for oxygen.**
- **The Model 1A3B is factory-calibrated to read in percent saturation so that efficiency of aeration or deaeration is shown directly. Or if preferred, the instrument can also be supplied to provide readings directly in parts-per-million.**
- **The Model 1A3B can be directly connected to any standard potentiometer-type recorder or indicator. No special accessory equipment is needed.**
- **Using the Model 1A3B is far superior—in speed, accuracy and convenience—to conventional chemical methods—and provides—immediately and continuously—the necessary control information for maintaining optimum processing uniformity.**

With a few variations the Model 1A3B can be adapted to a wide range of application requirements . . . to handling sludges and other liquids having high concentration of solids . . . to handling samples under abnormal pressures or temperatures . . . and to other difficult sampling conditions.


AIR CHECK INLET
4-WAY VALVE
OVERFLOW
SAMPLE EXIT
WIDE CIRCULAR WEIR SCRUBBING TOWER
VIBRATOR 1046
ARNOLD O BECKMAN OXYGEN ANALYZER
RECORDER OR INDICATOR
SCRUBBING GAS CYLINDER
POROUS DISC
ZERO SET CONTROL VALVE
MOUNTING PAD
FLOW CONTROL NEEDLE VALVE
PUMP FOR SAMPLES WITH SOLIDS - POSITIVE DISPLACEMENT
HIGH PRESSURE EFFLUENT
INLET TUBE - BLOWN BACK ONCE PER HOUR BY HIGH PRESSURE EFFLUENT
SOLENOID VALVE & VIBRATOR ON FOR 10 SECONDS PER HOUR

The Principle is simple and positive. The constantly-fresh test sample in scrubbing tower is stripped of dissolved oxygen by inert scrubbing gas—and result measured by Analyzer. Measurement is continuous and accurate!

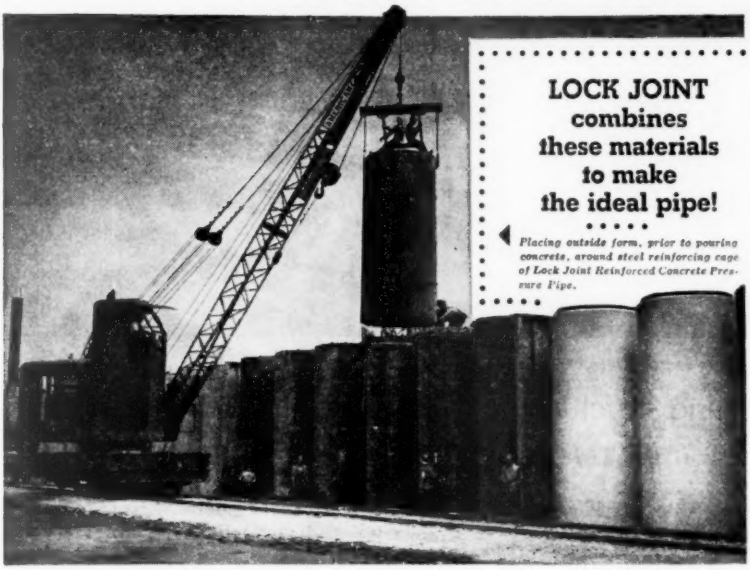
RANGES—from a maximum of 0-100% O_2 saturation to a minimum of 0-5 ppm, full scale. Intermediate ranges are also available.

Arnold O. Beckman INC.

1020 MISSION STREET, SOUTH PASADENA 19, CALIFORNIA

Get the full story *on this new Arnold O. Beckman development by writing directly for information on the Model 1A3B Dissolved Oxygen Analyzer. Ask for Data File # 13-0-114.*

There's no substitute for CONCRETE and STEEL!



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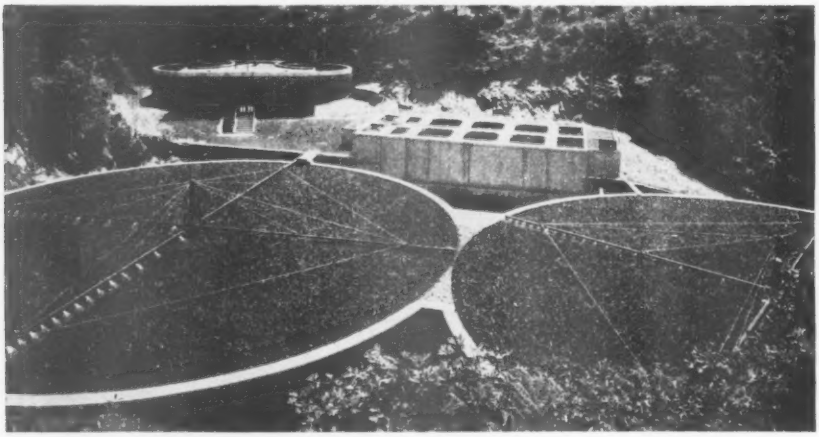

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SEWAGE AND INDUSTRIAL WASTES

Journal of the Federation of Sewage and Industrial Wastes Associations

Volume 26 **November, 1954** **Number 11**

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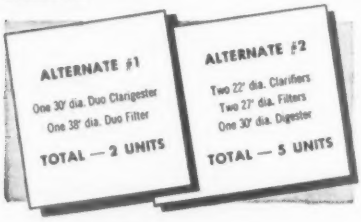

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Sewage Works

DISPOSAL OF DIGESTED SLUDGE BY DILUTION *

By A M Rawn and F. R. Bowerman

Respectively, Chief Engineer-General Manager and Division Engineer, Los Angeles County Sanitation Districts, Los Angeles, Calif.

The decision to dry digested sewage sludge as a means of conserving its fertility values for plant culture is usually dependent upon the cost involved in conditioning the sewage sludge for use. In areas where inexpensive open-air sludge drying methods may be used, or where the value of the finished product is sufficient to return the cost of mechanical drying, the decision is not difficult. If such conditions do not obtain and the cost of reclamation outweighs the value of the reclaimed sludge, it may be inappropriate to subsidize sewage sludge conservation unless reclamation is necessarily concurrent with final disposal. Where it is not, sewage disposal authorities usually seek another method. Cities favorably located with respect to large bodies of water may find it possible to safely utilize dilution methods for the disposal of digested sewage sludge.

Disposal *vs.* Conservation

For ages, sewage has been recognized as a material to be used for increasing soil fertility. Although sewage sludge does not contain enough nitrogen and phosphoric acid to compete directly with inorganic fertilizers, in addition to its fertility values it does possess humus properties which condition the soil to hold moisture and permit the ready passage of air, encouraging growth and general vitality of plant life. All organic wastes have this facility and throughout the world where farming has been conducted intensively for centuries (for example, the Orient, South Africa, and the Netherlands), the yield of the land has been maintained by carefully returning to the soil all the organic materials that can be obtained.

In America, the tendency all too often has been to utilize farm areas without much regard for the future; in some instances the soil fertility has been reduced to the point where the land is no longer of economic value for farming. A realization of the need for farming techniques which maintain a proper organic balance in the soil is slowly developing; in such a picture, sources of organic materials such as sewage sludge will become increasingly valuable. There is an increasing awareness that the future security of America's farm production necessitates a return to the soil of those essential minerals and organics which are so requisite to continued intensive farming. From this it would appear that every effort should be made to conserve sewage sludge at all costs. However, reflection on the available sources of organic solids will quickly dispel the notion that sewage sludge is indispensable to the organic market.

The sanitary engineering field in recent years has recognized the close relationship that exists between the fields of sewerage and refuse collection and disposal. No clearer example of this can be shown than in the use of

* Presented at 26th Annual Convention, California Sewage and Industrial Wastes Assn.; Sacramento, Calif.; May 5–8, 1954.

sanitary sewers for the transportation of ground garbage solids. Recent studies by the County Sanitation Districts of Los Angeles County show that in the Los Angeles metropolitan area, with a total population of almost 5,000,000 people, the daily production of organic refuse is about 6,000 tons. This organic material consists of paper, cardboard, grass, leaves, brush and tree trimmings, and rags, combined with leather, plastic, rubber, transient metal, and such heterogeneous objects as are invariably found in rubbish. Composting experience in Europe, New Zealand, South Africa, and in a few places in America would indicate that perhaps three-fourths of this material, or 4,500 tons, can be transformed into a humus-like soil conditioner. The total production of digested sewage sludge in the same area is about 400 tons per day.

From this it appears that composting as a source of humus may afford some 10 times the potential of digested sewage sludge. This is not to discount the value of sewage sludge as a soil builder, but merely to suggest a need for an evaluation of the total picture. To plead for the conservation of one source of organic material (that is, sewage sludge) without considering the present practice of wasting much larger sources of organic materials does not seem consistent.

Sewage sludge conservation should be viewed dispassionately and in the cold light of engineering economy. In general, the conservation of sewage sludge should be practiced where the processes involved in preparing sewage solids for the ultimate market are such as to show a favorable economic balance. Conversely, where it can be shown that the disposal of sewage sludge will effect an over-all economy, it appears reasonable to waste rather than to conserve the organic solids.

The economic value of sewage sludge fluctuates according to demand, and since storage is expensive and many times inappropriate it may, in some instances, prove desirable to exercise a choice between conservation and waste depending upon the current sludge market. Sewerage authorities, practicing sludge conservation, may desire to waste sludge during periods when the market value of the conditioned sludge does not justify its reclamation. To be forced to the necessity of uneconomical sludge reclamation may prove to be an expensive imposition.

The wastage of sewage sludge is presently practiced in many locations. Examples include New York City, where sludge is barged to sea in ocean-going vessels, and Detroit, Mich., where the sewage sludge is incinerated in multiple-hearth furnaces. There are many, many others. What follows is a discussion of digested sludge disposal by dilution and has application to sewage treatment plants suitably located near large bodies of water.

Digestion Basic to Effective Disposal

The physical nature of crude sewage solids, in particular those from the primary phase of sewage treatment, is such as to render disposal by dilution difficult because of the likelihood that nuisances will result. The floatable components of crude sewage sludge tend to travel long distances at the surface, maintaining identity, and in some instances reaching recreational areas. In addition to being repugnant to sight and smell, undigested sewage solids harbor pathogenic organisms which are hazards to health and are virtually impossible to reach and destroy by any known means of disinfection. Additionally, undigested sewage solids exert a strong biochemical oxygen demand on the receiving waters, creating odor problems and endangering aquatic life unless large volumes of diluting water are immediately available.

Anaerobic digestion of sewage solids

radically alters the nature of the material, rendering it amenable to rapid mixing and dispersion in water. The process of decomposition transforms greasy solids, which tend to cling together, into stable components which have lost the greasy, sticky properties. In effect, digestion of sewage sludge is a homogenization and reduction process which produces a fairly uniform end product similar to humus. The change is more than physical or chemical inasmuch as the disease-creating potential of the sludge is greatly reduced. Tests made several years ago by the Los Angeles County Sanitation Districts (1) demonstrated that 30-day detention in a digester at temperatures of from 95° to 100° F. reduced the coliform density per milliliter from 1,500,000 organisms to 3,000, an effective reduction of 99.8 per cent.

Although it is difficult to measure precisely the B.O.D. of sewage sludge, an estimate of the reduction resulting from anaerobic digestion may be obtained by dilution methods. Tests referred to previously (1) indicate that the reduction in strength of sewage sludge digested for a 30-day period appears to be about 90 per cent. Where the acceptability of the dilution method might be questioned because of the oxygen demand, it appears desirable that the initial demand be reduced through digestion.

As discussed previously, the components in sewage sludge which are most apt to create nuisances are those which float. Sludge digestion tanks are customarily designed so that the point of drawoff is at or near the bottom of the tank, a feature which prevents the discharge of readily floatable materials in the digested sludge. Crude sewage solids which float will become a part of the scum layer in the digester until they are biologically altered and stabilized, at which time they either become a gas, enter into the liquid phase, become discrete solids with a density greater than that of the surrounding medium and sink to the bottom, or remain as a part of the floating scum within the digester. It is not anticipated that scum would be considered suitable for disposal by dilution; scum should be disposed of so as to prevent the formation of floating, wind-driven "islands"; the most feasible means of disposal will probably be either incineration or burial.

In some cases it may be desired to discharge digested sewage sludge intermittently, to take advantage of strong currents, ebbing tides, or unique climatic or oceanographic circumstances. Sludge digestion in closed tanks provides storage for the digesting matter, permitting the discharge to be made at the will of the operator. Where bathing and other recreational uses are restricted to certain times of the year when relatively mild air and water temperatures prevail, it may be possible to waste digested sewage sludge during the off-seasons so as to meet all nuisance requirements excepting those health standards prescribed for bathing beaches. Inasmuch as bathing-water criteria are adopted to protect public health, the bacteriological degradation of littoral waters during non-bathing seasons may be considered completely compatible with requirements for health protection. An exception to this would be where shellfish beds might be adversely affected by the discharge.

Dilution Techniques

Once the problem has been clearly defined as one in which the disposal of sludge will effect an economy in operation when compared with conservation, and, further, where the conditioning of the sewage solids through digestion will yield a substance which will mix readily with water and disperse rapidly, the solution becomes solely a matter of analysis of the particular geographical and oceanographical factors at hand. It appears entirely feasi-

ble that in most cases where disposal of primary sewage effluents is presently and adequately made, the discharge of digested sewage sludge may also be accomplished in full compliance with all requirements for health and safety.

Provided currents are sufficient to effect a periodic exchange of polluted water with well-aerated salt water, it is practical to cause a dispersion at the point of disposal sufficient to prevent depletion of the dissolved oxygen. A further requirement for satisfactory disposal by dilution is that the travel of the sewage-polluted water be in such direction and of such duration as to assure that concentrations of coliform bacteria at bathing beaches or recreational areas will not reach the levels that will result in a potential health hazard.

The State of California, through its Regional Water Pollution Control Boards, has defined certain criteria for the disposal of sewage effluents into littoral waters. Regional Water Pollution Control Board No. 4, which comprises the Los Angeles-Ventura watersheds, has requirements as follows:

1. No grease, oil, or visible solids of waste origin in receiving waters or on beaches or shores.

2. "Unavoidable discoloration of receiving waters or oily slicks in the immediate vicinity of sewer and industrial waste outfalls may be permitted, providing no established beneficial use is adversely affected. . . ."

3. No ". . . odors in the receiving water or along adjacent beaches or shores such as that they may constitute a nuisance."

4. Coliform densities to conform to State Board of Public Health requirements.

5. No ". . . concentrations of toxic materials in the receiving waters which would be detrimental to human, animal, fish, plant, or bird life."

6. No ". . . sludge banks or deposits on the ocean floor or along adjacent shores or beaches to the extent that they would significantly interfere with development of marine life or would cause nuisance due to odors or unsightliness."

It should be noted from examination of these criteria that the disposal of digested sewage sludge introduces but one additional factor aside from those attendant upon the disposal of sewage effluent: the question of formation of sludge banks. It is also of interest to note that sludge banks are not considered inherently damaging, but that they are to be subject to review on the basis that they "significantly interfere with development of marine life or would cause nuisance due to odors or unsightliness."

It may be possible in many instances to effect proper disposal of digested sewage sludge by dilution in lakes or rivers. However, fresh-water lakes and rivers are often sources of drinking water and in many instances are either too small to enable immediate effective dilution or lack currents sufficient to replace polluted water with fresh water. The problems involved in achieving a satisfactory disposal of digested sewage sludge may be difficult to solve in such cases. A unique case is that of Portland, Ore., situated near the Columbia River, where the enormous volumes of water available for dilution indicate clearly that the disposal of sludge will pose no problem, the Columbia River seldom flowing at a rate less than 100,000 cu. ft. per second (2). In the opinion of the Engineering Board which formulated a master plan for the disposal of Portland's sewage, it was entirely feasible to dispose of the untreated raw sewage directly to the river without creating nuisances or endangering public health; however, the Board felt that the modest cost of primary sewage treatment, when combined with

the disposal of the digested sewage sludge by addition to the primary effluent with final discharge to the river, was a small price to pay for the additional safeguards provided.

Fewer problems are presented by disposal to the ocean, except where ocean waters are confined to estuaries, harbors, or bays; however, even here it may be possible to utilize dilution methods for disposal of digested sludge. In general, to be acceptable in confined waters some particularly favorable circumstance must be present to enable the disposal to be made without nuisance. For example, the primary sewage treatment plant of the East Bay Municipal Utility District, located adjacent to the Oakland terminus of the San Francisco-Oakland Bay Bridge, has satisfactorily practiced the disposal of digested sewage sludge through its outfall sewer since 1952. Although the discharge occurs at a depth of only 40 ft. in mid-channel, the coincidence of discharging sludge with ebbing tide assures that the flushing action of the currents will carry the digested sludge rapidly into the open reaches of San Francisco Bay, where it disperses and disappears without causing nuisance or endangering public health. The decision to waste sewage sludge in this instance was in part occasioned by the lack of land on which to install sludge drying and conditioning equipment.

The disposal of digested sewage sludge to littoral zones swept by strong ocean currents presents what is almost an ideal set of circumstances for the use of this method. Where an ocean outfall has already demonstrated its ability to dispose of primary effluent adequately without creating pollution or endangering public health, there appear to be no valid reasons why digested sewage sludge cannot be disposed of by the simple expedient of introducing it into the outfall along with the primary effluent. If digested sewage sludge is mixed with a primary effluent similar to that discharged from the Joint Disposal Plant of the Los Angeles County Sanitation Districts (1), it would alter the nature of the primary effluent in the following manner:

1. Increase the 5-day B.O.D. by about 2 per cent.
2. Increase the settleable solids by about 1.5 ml. per liter.
3. Effect a slight decrease in the concentration of coliform bacteria, inasmuch as the sludge contains less organisms per unit volume than the primary effluent.
4. Increase the total grease content about 20 per cent, this largely consisting of miscible or emulsified forms.
5. Increase the chlorine demand by about 5 per cent.

Disposing of digested sewage sludge by dilution is not confined to the mixing of sewage effluent and sludge with discharge through a common outfall. At times it may be desirable to construct a completely separate outfall for the express purpose of discharging the digested sewage sludge at such depth and distance from shore that no opportunity is afforded for the chance return of the material to the shoreline. Some reasons which would suggest the construction of a separate sludge line are as follows:

1. Inadequacy of near-shore currents to protect against the formation of sludge banks in areas where significant damage to bottom-dwelling marine organisms might result.
2. Depths too shallow to afford the necessary initial dilution and dispersion.
3. The possibility that increased turbidity in near-shore waters may decrease sunlight transmission and thereby alter the environment in such a manner as to affect marine flora and fauna.

Construction of a separate sludge line can be done economically through

choice of engineering techniques which are available for laying small-diameter submarine pipes without the use of expensive equipment and divers. One technique used successfully in the Gulf of Mexico has been the placing of steel pipelines, welded into a single length, and pulled into place with offshore tugs and barges. Such an outfall can be protected from the corrosive effect of salt water by cathodic means. At Ventura, Calif., a 21-in. diameter steel line, extending 2,400 ft. from shore into the Pacific Ocean, was placed in 1938 and remained without protection until 1950, at which time underwater investigation showed that deterioration had reduced the shell to about one-half its original thickness. To prevent continued damage, cathodic protection was installed in 1952; subsequent investigation shows that no apparent deterioration has occurred since the time of installation of a cathodic protective device.

From oceanographical considerations, it may be possible to achieve sufficient immediate dilution at the ocean's floor by use of an aspirator or jet pump to increase the density of the sludge-sea water mixture to the point that it will remain submerged on the ocean's floor in bottom areas specifically chosen for the final disposal of the wasted sludge.

Conclusions

Disposal of sewage sludge which cannot be economically transformed into useable end-products may be accomplished by several methods, including burial, incineration, and wastage to large bodies of water. The latter method has sometimes been construed to be unsatisfactory because of difficulties encountered in the past with the disposal of raw sewage. The factors which make the disposal of sewage sludge by dilution acceptable are as follows:

1. Bacterial decomposition in sludge digestion tanks alters the character of the crude sewage solids, changing them into a relatively homogeneous matter with significantly less oxygen demand and lower pathogenic content—a substance amenable to ready dispersion when mixed with volumes of water.

2. Reconstitution of digested sewage sludge with a primary effluent and discharge through a common outfall may reasonably be accomplished in almost all instances where primary effluents are now being adequately disposed of to lakes, rivers, or oceans.

3. Separate sludge outfalls may be constructed where mixing of digested sewage sludge with effluent may jeopardize health and safety standards. Separate sludge outfalls, being small-diameter pipes, can be placed economically and carried to such distances and depths as to insure satisfactory disposal, provided oceanographic considerations are observed in the design and location of the outfall.

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BIOLOGICAL REDUCTION OF SODIUM CHLORATE AS APPLIED TO MEASUREMENT OF SEWAGE B.O.D.

By Edward H. Bryan and Gerard A. Rohlich

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Determination of the amount of oxygen required to biochemically oxidize the organic material present in sewage, and determination of the capacity of the receiving body of water to supply this oxygen, have been of great value as a laboratory approach to the problem of predicting the pollutional effect of sewage. The limitations of the dilution method for the determination of the B.O.D. of sewage were recognized by Mohlman (1) who summarized them as follows:

"The limitations of the dilution method are well known, namely, the limited solubility of atmospheric oxygen, and consequent high dilution factors; the difficulty of obtaining a reproducible, zero-demand dilution water; the problem of seeding sterile or bactericidal liquors; and the 'marginal' errors due to too high or two low depletions."

The use of synthetic dilution waters reduced much of the inconsistency that was associated with the dilution method; however, the recent work of Lewin (2) is cited to call attention to inconsistencies resulting from use of different dilution waters.

Lederer (3)(4) introduced a procedure for measuring the oxygen demand of wastes and polluted waters by determination of the oxygen equivalent of the nitrate (self-contained or added) that was biochemically reduced during a suitable incubation period. The Lederer nitrate method was subsequently adopted as a "standard method" by the American Public Health Association (5). Since there was relatively no limit to the amount of oxygen as nitrate that could be provided during incubation, the oxygen demand of sewage could be determined without dilution. The excess oxygen or dilution method has been preferred, however, for one or more of the following reasons:

1. The facility with which the sample of sewage is prepared for incubation is largely offset by the later determinations for residual nitrite and nitrate (6).
2. The excess oxygen method more closely simulates natural conditions of dilution and reaeration.
3. It has been shown that with proper precautions, the excess oxygen method can give consistent results over the recommended range of oxygen depletion.

Zehnpfennig (7) suggested the possible use of sodium chlorate as a source of combined oxygen. If the reduction of chlorate proceeded to chloride, and if chloride appeared in proportion to the concentration of biochemically oxidizable matter initially present, the relative ease with which concentrations of chloride ion can be measured might make this a more acceptable combined oxygen procedure than the Lederer nitrate method.

Agriculturists have investigated the possibility of biochemical reduction as an explanation for the disappearance of chlorate from soil to which chlorate had been applied for the purpose of weed control. Aslander (8) observed

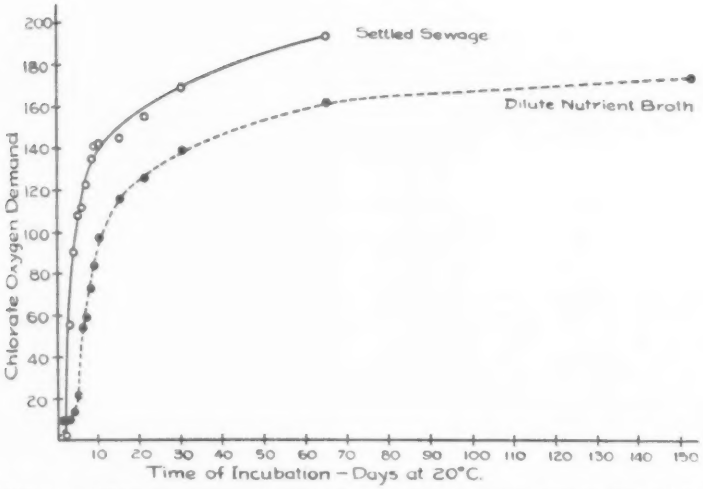

FIGURE 1.—Chlorate oxygen demand of a settled domestic sewage and of a dilute nutrient broth seeded with settled sewage.

a climatic gradient in the weed-killing effectiveness of chlorates in that their activity was greater the farther north they were used. He found that chlorates decomposed in soil at 30° C. Species of *Penicillium*, *Aspergillus*, and *Fusarium*, growing on the surface of hay infusions containing N/10 sodium chlorate solution, changed its strength to N/15 in 60 days. Bacteria were observed growing in the liquid portion of the infusion. He also observed that decomposition of chlorates took place in soil that was saturated with water.

Crafts (9) and Rosenfels and Crafts (10) questioned the interpretation of the observed relation between soil fertility and chlorate toxicity (that the organic matter in soil reacts with chlorate in a biochemical process) and suggested that phenomena other than chlorate reduction were apparently involved. Evidence of a stimulatory effect on nitrification by the presence of chlorate is contained in their data. Karrer (11) and Nelson (12) favored the interpretation that chlorate toxicity to weeds was reduced by disappearance of chlorate through the activity of microorganisms, a condition that was stimulated by acidity, warm temperatures, and moist conditions.

Quastel, Stephenson, and Whethem (13) observed that hypochlorite, a possible intermediate reduction product of chlorate, was not formed when resting cells of *Escherichia coli* were allowed to act on lactate anaerobically in the presence of chlorate, although the presence of chlorite was demonstrated. Chlorite was found to be toxic to *E. coli* at a concentration of 50 p.p.m.

Preliminary Experiments

To investigate the possible use of sodium chlorate as a source of combined oxygen, settled sewage and dilute nutrient broth seeded with settled sewage were placed in a series of bottles containing an estimated excess of sodium chlorate. The dissolved oxygen and chloride concentrations were determined for the sewage-chlorate mixtures initially and following incubation at 20° C. The results (Figure 1) indicated that chlorate was reduced at a varying rate, similar to that observed in the standard B.O.D. determination.

To further evaluate a "chlorate oxygen demand" procedure, the following steps were carried out:

1. The 5-day B.O.D. and the 5-, 10-, or 20-day chlorate oxygen demands were determined for sewage obtained from several sources.

2. Known amounts of glucose were added to settled or raw sewage and the oxygen demand of the resultant mixtures determined by both the dissolved and combined oxygen demand procedures.

3. The dissolved oxygen and combined oxygen demands of a synthetic sewage in mixture with settled sewage were compared.

B.O.D. Comparison

The analytical procedures for the determination of the 5-day B.O.D. and the chloride concentration were those recommended for use by Standard Methods (14), the Mohr method being used for chloride determination. The chlorate oxygen demand was determined as follows:

1. Sodium chlorate solution of desired strength was placed in 300-ml. B.O.D. bottles.

2. Sufficient sewage was siphoned into each bottle so that when the glass stopper was inserted, the bottle was completely filled.

3. The bottles were placed in an incubator and kept at 20° C. for the desired incubation period.

4. The dissolved oxygen and chloride concentrations were measured at the start and conclusion of the incubation period.

The 5-day B.O.D. and the 10-day chlorate oxygen demand were determined for approximately 60 different samples of sewage. The 5-day chlorate oxygen demand was determined for approximately 30 samples and the 20-day chlorate oxygen demand was determined for 15 samples.

Results and Discussion

The results of these studies are plotted in Figures 2, 3, and 4. A direct linear relationship was found to exist between the 5-day B.O.D. of a waste and its 5-, 10-, and 20-day chlorate oxygen demand. The chlorate oxygen demand of settled sewage after incubation for 5, 10, and 20 days at 20° C. was found to be, respectively, 0.64, 0.76, and 0.87 of the 5-day B.O.D.

It is evident that a 10-day incubation period extends the range over which the chlorate oxygen demand determination results are linearly related to the 5-day B.O.D. A 5-day incubation period was adequate for sewage having a strength of less than 100 ppm. of 5-day B.O.D. Initial disturb-

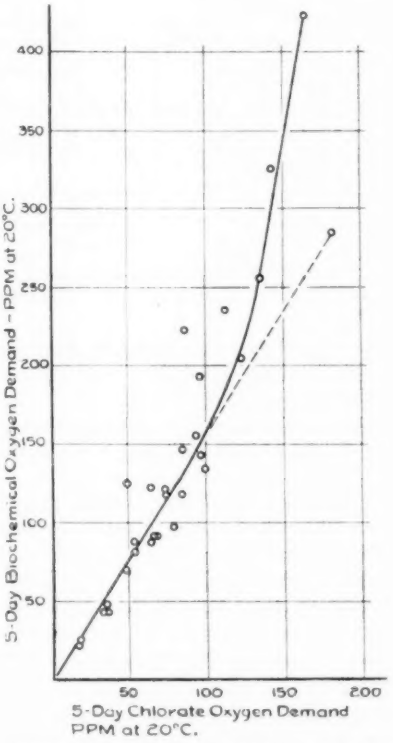

FIGURE 2.—Relationship between 5-day B.O.D. and 5-day chlorate oxygen demand of sewage.

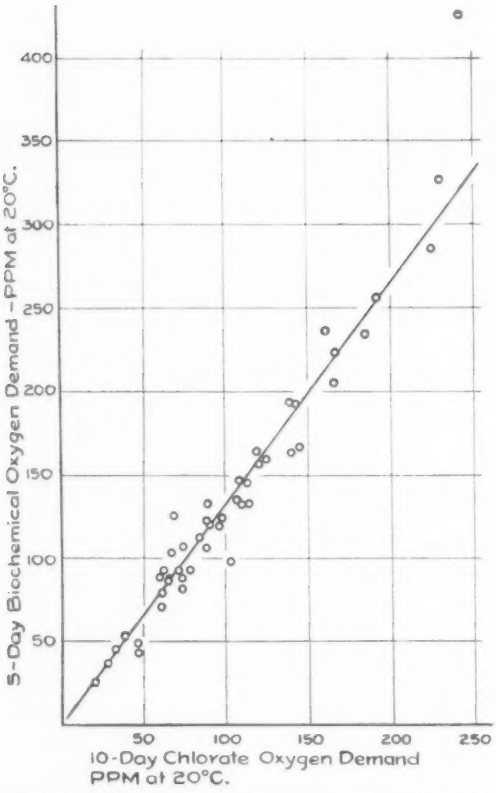

FIGURE 3.—Relationship between 5-day B.O.D. and 10-day chlorate oxygen demand of sewage.

ances, such as an unusually long lag period during which little chlorate reduction occurred, would show their effect more noticeably after incubation for 5 days than 10 days. Moreover, the greater the waste strength, the longer the period required for oxidation of a fixed percentage of the total oxidizable material present. This is evident from Figure 1. The initial oxidation rate for the settled sewage was higher than that of the relatively poorly inoculated, dilute nutrient broth. The maximum rates of chlorate reduction for both the settled sewage and the dilute nutrient broth are comparable; however, the maximum rate continued for a longer interval of time for the stronger settled sewage, thus resulting in a higher ultimate oxygen demand. The comparable state of oxidation of settled sewage at the end of 10 days, when 73 per cent of the 65-day chlorate oxygen demand had been satisfied, was reached by the dilute nutrient broth after incubation for 17 days.

From these results, it may be concluded that the chlorate oxygen demand is as proportional to the amount of biochemically oxidizable matter present in sewage as is the 5-day B.O.D.

Oxygen Demand of Glucose

The chlorate oxygen demand of glucose was determined by the following

procedure. Settled sewage (100 ml.) was placed in each of a series of 300-ml. B.O.D. bottles. A sodium chlorate solution of known strength was added to each bottle. Following addition of glucose, the bottles were completely filled with dilution water, stoppered, and placed in an incubator at 20° C. The dissolved oxygen and chloride concentrations were determined initially and following incubation.

The increment of 10-day chlorate oxygen demand corresponding to a concentration differential of 50 p.p.m. of glucose was 23.6 p.p.m., while the comparable value for the 5-day B.O.D. was 33.4 p.p.m. (averages of 18 determinations). These values are, respectively, 44.2 and 62.6 per cent of the calculated ultimate oxygen demand of 50 mg. of glucose. The standard deviation from the mean for the 5-day B.O.D. of 50 mg. of glucose was ± 5.3 mg.; that for the chlorate oxygen demand was ± 4.6 mg.

Oxygen Demand of Synthetic Sewage

Varying amounts of a synthetic sewage of the same relative composition as that used by Butterfield, Ruechoft, and McNamee (15) were added to settled sewage, following a procedure similar to that described for controlled additions of glucose.

The average value for the 10-day chlorate oxygen demand for a concentration differential of 50 ml. of synthetic sewage per 308 ml. of solution was 32.2 p.p.m. (average of 9 results); the corresponding value for the 5-day B.O.D. was 45.5 p.p.m. The standard deviations from the mean for these values were ± 5.35 p.p.m. for the 10-day chlorate oxygen demand, and

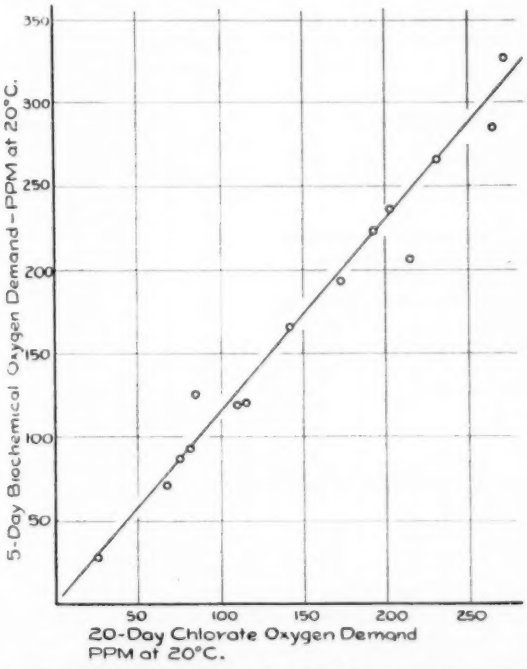

FIGURE 4.—Relationship between 5-day B.O.D. and 20-day chlorate oxygen demand of sewage.

TABLE I.—Effect of Chlorate Concentration on Chlorate Oxygen Demand of Settled Sewage[1]

Oxygen Added as Chlorate (p.p.m.)	Incubation Period (days)	Chlorate Oxygen Demand (p.p.m.)
54.1	5	58.1
	10	54.5
	32	—
108	5	79.5
	10	109
	32	114
216	5	85.5
	10	112
	32	147
324	5	83.5
	10	113
	32	145

[1] B.O.D. (5-day, 20° C.) of settled sewage was 147 p.p.m.

± 9.08 p.p.m. for the 5-day B.O.D. The ratios of the 10-day chlorate oxygen demand to the 5-day B.O.D. for added increments of glucose and synthetic sewage were 0.707 and 0.710, respectively.

Chlorate Concentration

The concentration of sodium chlorate in settled sewage was varied in such a manner as to insure the presence of an excess in one group of bottles and a deficiency in another group. From the results of this experiment (Table I) it is apparent that in 5 days all of the sodium chlorate had been reduced to sodium chloride in those bottles initially containing 54 p.p.m. of combined oxygen. At the end of 10 days, all of the chlorate in those bottles containing 108 p.p.m. was accounted for by the increase in chloride concentration. There was no significant difference in the amount of chlorate reduced when chlorate was present in excess. These results were confirmed by a similar experiment in which sodium chlorate was added to settled sewage in large excess. From the results of

TABLE II.—Effect of Chlorate Concentration in Large Excess on Chlorate Oxygen Demand of Settled Sewage

Series	Oxygen Added as Chlorate (p.p.m.)	Incubation Period (days)	Chlorate Oxygen Demand (p.p.m.)	5-Day B.O.D. (p.p.m.)
X	400	5	57.4	91.9
		10	67.3	91.9
X	600	5	56.9	91.9
		10	68.6	91.9
Z[1]	500	5	177	285
		10	229	285
Z[1]	1,000	5	183	285
		10	221	285

[1] Series Z consisted of bottles filled with a synthetic sewage (15) seeded with 10 per cent settled sewage.

TABLE III.—Effect of Chlorate Oxygen Demand on Reduction of 5-Day B.O.D.

Incubation Time (days)	Chlorate Oxygen Demand (p.p.m.)	Reduction of 5-Day B.O.D. (p.p.m.)	Ratio, B.O.D. Red. / Chl. Oxy. Demand
5	37.0	30.0	0.811
10	67.4	69.6	1.032
10	46.8	36.1	0.772
31	25.8	>21.6	>0.837
31	78.1	56.6	0.725
31	124	98.8	0.796
31	221	164	0.742
36	90.1	71.8	0.796
42	48.4	38.7	0.800
42	82.1	68.3	0.832
42	116	99.0	0.853
42	168	143	0.851
42	140	110	0.786
42	99.6	75.6	0.759
42	158	120	0.758
42	186	132	0.711
42	213	160	0.750
48	108	76.5	0.709
48	50.1	43.3	0.865
48	25.2	21.6	0.856
48	15.7	11.2	0.713
59	246	191	0.776
59	170	141	0.830
59	94.7	76.4	0.806
59	132	109	0.825
153	176	154	0.875
Average (Excluding 1.032)			0.793
Median (Excluding 1.032)			0.800
Standard deviation			±0.051

this experiment (Table II) it is again apparent that the reduction of sodium chlorate is independent of its concentration. There was no apparent inhibitory effect on chlorate reduction resulting from the presence of as much as 1,000 p.p.m. of chlorate oxygen.

5-Day B.O.D. Reduction

The 5-day B.O.D. of sewage-chlorate mixtures after incubation for various time intervals was determined. The dilution water used was seeded with settled sewage. In several instances, a sufficient number of replicates were prepared to observe daily changes in chlorate reduction, B.O.D., and the reduction of 5-day B.O.D. (Table III). Previously incubated sewage-chlorate mixtures were used to seed fresh sewage-chlorate mixtures. The results obtained by the use of a single large bottle were compared to those obtained by the use of the multiple-bottle technique.

Since the change in 5-day B.O.D. may be considered to be directly related to the "disappearance" of biochemically oxidizable material, the data of Table III further substantiate the conclusion that the reduction of sodium chlorate is directly proportional to the amount of biochemically oxidizable material originally present in sewage.

The results obtained through use of a single incubation bottle as compared to those obtained through use of the multiple-bottle technique (for daily observations) are shown in Figure 5. Chlorate oxygen demand results from both procedures are clearly comparable. Among the advantages of the single-bottle technique are reduced incubator space required, reduced labor in filling and cleaning bottles, and elimination of variability between replicate bottles. In the single-bottle procedure, sodium chlorate solution was added to sewage and the mixture was siphoned into an aspirator-type bottle, which was then stoppered. The atmosphere over the chlorate-sewage mixture was then flushed with nitrogen and the bottle placed in an incubator. When samples were withdrawn, additional nitrogen was admitted.

The effect of inoculation with previously incubated chlorate-sewage mixtures in which chlorate reduction had occurred is shown in Figure 6. Inoculation decreased the time interval

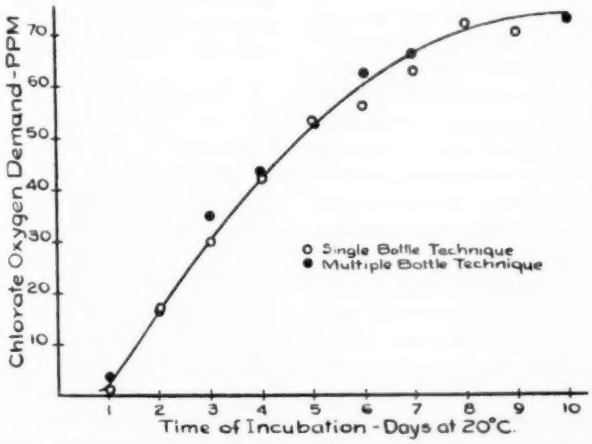

FIGURE 5.—Comparison between the single- and multiple-bottle techniques for determination of chlorate oxygen demand.

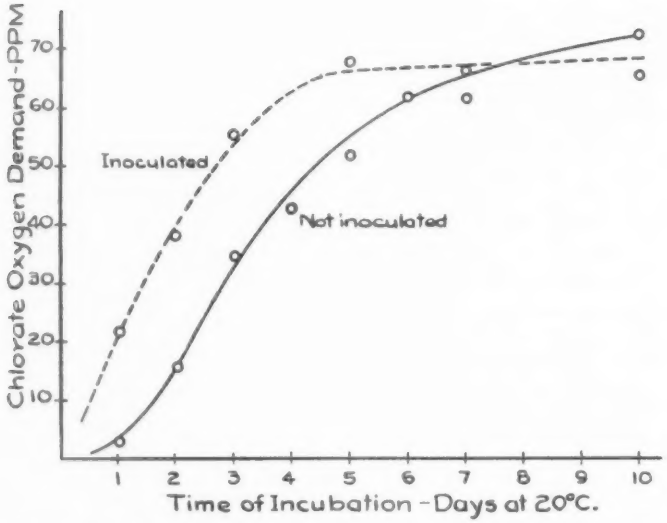

FIGURE 6.—The effect of inoculation with a previously incubated chlorate-sewage mixture, in which chlorate reduction had occurred, on the chlorate oxygen demand of settled sewage.

prior to rapid reduction of chlorate. There was no evidence of an increased maximum rate of chlorate reduction as a result of the presence of an inoculum.

Bacteriological Studies

Preliminary bacteriological studies indicated that pasteurization at 85° C. for 10 min. did not destroy the capacity of previously incubated sewage-chlorate mixtures (in which chlorate reduction had occurred) to supply chlorate reducing activity when used as an inoculum for sterile sewage. Pure cultures of *Escherichia coli*, *Aerobacter aerogenes*, *Serratia marcescens*, *Proteus vulgaris*, *Bacillus macerans*, and *Pseudomonas fluorescens* did not reduce sodium chlorate to chloride when inoculated into sterile sewage under conditions of the test. Plate counts made after two successive enrichments of chlorate-sewage mixtures (in which chlorate reduction had occurred) into sterile sewage led to the conclusion that an increase in numbers of organisms was associated with reduction of sodium chlorate.

Summary and Conclusions

A new method for the determination of the oxygen demand of sewage is presented and its applicability for measurement of the biochemical oxygen requirements of sewage is demonstrated. It is concluded that:

1. The relative amount of biochemically oxidizable material present in sewage can be determined by incubating the sewage, in mixture with an excess of sodium chlorate, under conditions that exclude atmospheric oxygen, and measuring the increase in chloride concentration that occurs.

2. In the determination of the chlorate oxygen demand, a 5-day incubation period was shown to be adequate if the oxygen requirements of the sewage did not exceed 100 p.p.m. (5-day B.O.D.). A 10-day period of incubation is recommended.

3. Inoculation of fresh sewage-chlorate mixtures with mixtures remaining from a previous enrichment in which chlorate reduction had occurred, reduced the time interval required for commencement of rapid chlorate reduction. Inoculation had no apparent effect on the maximum rate of chlorate reduction or on the ultimate oxygen demand of the sewage.

4. The chlorate oxygen demand is independent of the concentration of sodium chlorate, provided the sodium chlorate is added in excess of the oxygen requirements of the sewage and the amount added is not inhibitory to the organisms concerned in effecting the reduction of chlorate.

5. The 10-day chlorate oxygen demand test, as proposed, measured increments of glucose and synthetic sewage (added to settled and raw sewage) with as good a degree of precision as did the 5-day B.O.D.

6. Pasteurization (85° C. for 10 min.) did not reduce the ability of previously incubated chlorate-sewage mixtures to furnish chlorate reducing activity to sterile sewage. None of eight organisms tested alone in sterile sewage was capable of effecting the reduction of chlorate to chloride.

APPENDIX—SUGGESTED PROCEDURE FOR MEASUREMENT OF THE CHLORATE OXYGEN DEMAND OF SEWAGE

This method is based on the reduction of sodium chlorate by the action of microorganisms in the presence of oxidizable organic material and in the absence of dissolved oxygen. The reduction of sodium chlorate, which is added in excess to sewage, results in an increase in sodium chloride concentration which is proportional to the concentration of biochemically oxidizable material originally present. The amount of reduction is, within reasonable limits, independent of the concentration of chlorate, provided the chlorate is present in excess.

Reagent

Stock sodium chlorate solution may be prepared by dissolving 34.2 g. of sodium chlorate in distilled water and diluting the solution to 1 l. One milliliter of this solution when diluted to 308 ml. will provide a concentration of 50 p.p.m. of combined oxygen in the resulting mixture. The strength of the sodium chlorate solution may be varied for convenience.

Procedure

Add the sewage directly to a glass-stoppered bottle containing an estimated excess of sodium chlorate. When the glass stopper is inserted, the bottle should be completely filled. A sufficient number of bottles should be filled so that it is possible to measure the initial concentration of dissolved oxygen, the initial concentration of chloride ion, and the final concentration of chloride ion. The Mohr method for determination of the chloride concentration is recommended. A blank determination is not necessary if the aliquot for the initial chloride determination is identical in size with that taken for the final analysis.

The usual period of incubation may be taken as 10 days; the usual temperature, 20° C. It is recognized that for some wastes the period of adjustment during which little chlorate reduction occurs may be either unusually short or unusually long. In either event, the amount of chlorate reduction at the end of 10 days may not be a true indication of the relative strength of the waste. It is possible to reduce the incubation time required for oxidation of a fixed percentage of the ultimately oxidizable material by

inoculation of the fresh sewage-chlorate mixture with sewage-chlorate mixtures in which chlorate reduction had occurred. It may be necessary to seed some wastes with settled domestic sewage in order to insure the presence of organisms capable of effecting the reduction of sodium chlorate.

Calculation

The difference between the initial chloride concentration and the final chloride concentration, expressed in parts per million of NaCl, is multiplied by the factor 0.82 in order to obtain the chlorate oxygen demand of the waste, expressed in parts per million.

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EFFECT OF SEWAGE IRRIGATION UPON SOILS

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The purpose of the project reported here was to determine on a laboratory scale the effect of sewage irrigation as compared to tap-water irrigation on the physical and chemical properties of various soils.

Soils from six different locations were secured. The type of each was determined by the beaker method as given by Piper (1). All the tests were made, with slight modifications in some cases, according to the standard methods given by Piper and other writers on the subject.

Soil 1, a clay loam, was taken near Mitchell Lake, 8 mi. south of San Antonio, Tex. It had been irrigated with sewage for at least 10 years, sometimes used as pasture land, sometimes in cultivation. Soil 2, the same type as soil 1, was taken within 300 yd. of the soil 1 sampling location, but had not been irrigated. Soil 3 is a silty clay loam, soil 4 a sandy loam, and soil 5 a sand. Soil 6 is a sandy loam, differing from soil 4 in containing numerous small limestone particles.

The different soils are referred to herein by the numbers previously used; in addition sewage-irrigated soil 1 is referred to as soil 1a, and tap-water irrigated soil 1 is referred to as soil 1b; the other soils are numbered similarly.

The soils were prepared for the study in the following manner. Each soil was spread out on a flat surface to be air-dried. Substances not naturally part of the soil, such as rocks and pebbles, twigs and similar plant material were removed. Clods were crushed, but not ground. The remaining material was then properly mixed and quartered, sieved using a sieve with 2-mm. openings, and then filled into the pots. A portion of each soil was set aside for the other studies.

Table 1 gives the analyses of the tap water used and also of the sewage. The sewage is derived from the tap water.

Preparation of the Pots

The pots used were of glazed clay and about 0.3 cu. ft. in capacity, with a ½-in. hole in the bottom. A short piece of glass tubing inside of a rubber tube was fitted into each hole so the drainage water could be caught. A number of pebbles were placed around each tube to prevent clogging.

The water-holding capacity of each soil was determined according to Piper (1), but using Gooch crucibles instead of brass boxes. The soil was weighed as it was placed in the pot and slightly tamped while doing so. An amount of water according to the weight of the soil and its water-holding capacity was gradually added after each pot was filled. Two pots were prepared for each soil; pot a to be irrigated using settled sewage from the Austin, Tex., sewage treatment plant, pot b to be irrigated with tap water.

Irrigation Routine

Usually all soils were irrigated at the same time and received the same volume of either sewage or tap water. They were irrigated when the top soil was dry enough to break the crust to a depth of 2 to 3 in., the amount of irrigation water being determined by the appearance of drainage from the

TABLE I.—Analyses of Tap Water and Sewage

Designation	Magnitude	
(a) TAP WATER		
pH	9.7	
Dissolved solids	135	p.p.m.
HCO_3	21	p.p.m.
CO_2	16	p.p.m.
SO_4	21	p.p.m.
Cl	30	p.p.m.
NO_3	32	p.p.m.
Fe, total	0.03	p.p.m.
Si	6.4	p.p.m.
Ca	10	p.p.m.
Mg	9.7	p.p.m.
K	12.2	p.p.m.
Total hardness	65	p.p.m.
Non-carb. hardness	21	p.p.m.
(b) SEWAGE		
Total solids	450	p.p.m.
Volatile solids	300	p.p.m.
Suspended solids	140	p.p.m.
Ammonia	20	p.p.m.
BOD	144	p.p.m.
NO_2	0	p.p.m.
NO_3	0	p.p.m.

bottom of the pot. If the chlorides test was abnormally high, an extra amount of sewage or water added would carry this to the lower layers of the soil, as would happen in actual irrigation, either as a result of irrigation or occasional rainfall. The drainage from each pot was measured and analyzed for organic nitrogen.

The first irrigation took place Feb. 27, 1952, and the last on May 28, 1953. During that time 36 irrigations totaling about 54 l. of water or sewage were made to each pot. Based on the upper diameter of the pot, this amounts to about 35 in. during the 15 months, or 25 in. a year. All pots were irrigated with tap water for leaching purposes July 10 and 30, 1952, and March 26, 1953.

After May 28, 1953, the pots were gradually emptied as the soil dried out from the top down; the soil from each was stored separately to allow air-drying. About June 22, each soil was again spread out on a flat surface, rolled, sieved and quartered, and samples stored for the final analyses and tests.

Organic Nitrogen

Table II gives the total weight of the soil placed in each pot and the total weight of solids and organic nitrogen (1)(3) added during the study. The total amount of solids added is small, only 0.323 per cent of the total weight of soil 1a; for soil 3a, the least weight

TABLE II.—Summary of Irrigations and Organic Nitrogen

Soil[1]	Total Irrigation (l.)	Water Added[2] (l.)	Drainage (l.)	Solids Added (g.)				Organic N				Soil Used in Pots (g.)
				Susp.	Vol. Susp.	Total	Vol. Total	Added (g.)	Lost in Drainage (g.)	Total at Start (%)	Total at End (%)	
1a	53.65	7.75	7.00	10.13	7.07	36.48	18.60	2.24	0.06	0.0132	0.099	11,437
1b	53.40	5.75	1.35	—	—	—	—	—	0.01	0.0132	0.097	11,437
2a	53.65	7.75	9.68	10.13	7.07	36.48	18.60	2.22	0.12	0.133	0.098	9,947
2b	53.40	5.75	4.84	—	—	—	—	—	0.01	0.137	0.091	9,947
3a	51.75	7.75	10.67	9.83	7.04	35.19	17.95	2.13	0.07	0.125	0.068	8,887
3b	52.25	5.75	4.87	—	—	—	—	—	0.02	0.125	0.070	8,887
4a	52.00	7.00	8.12	9.92	7.08	35.36	18.03	2.14	0.06	0.182	0.085	10,059
4b	52.00	5.75	3.48	—	—	—	—	—	0.02	0.182	0.017	10,059
5a	52.75	7.00	6.11	9.93	6.99	35.87	18.29	2.00	0.05	0.022	0.009	14,035
5b	52.75	5.75	2.41	—	—	—	—	—	0.03	0.022	0.010	14,035
6a	53.20	7.00	8.59	9.93	6.99	36.18	18.45	2.18	0.06	0.160	0.102	9,248
6b	53.20	5.75	4.08	—	—	—	—	—	0.01	0.160	0.100	9,248

[1] Sewage irrigation denoted by a, tap-water irrigation by b.
[2] For chloride removal.

TABLE III.—Total Organic Nitrogen of the Soils

Soil[1]	Total Organic Nitrogen						
	At Start (g.)	Added (g.)	Lost in Drainage (g.)	Total Input[2] (g.)	At End (g.)	Lost[3] (g.)	Lost[4] (%)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1a	15.10	2.24	0.06	17.28	11.32	5.96	34.6
1b	15.10	0	0.01	15.09	11.09	4.00	26.7
2a	13.33	2.22	0.12	15.43	9.75	5.68	36.7
2b	13.33	0	0.01	13.32	9.05	4.27	32.0
3a	11.11	2.13	0.07	13.17	6.03	7.14	54.3
3b	11.11	0	0.02	11.09	6.22	4.87	40.3
4a	18.31	2.14	0.06	20.39	8.55	11.84	58.4
4b	18.31	0	0.02	18.29	1.71	16.58	90.3
5a	3.09	2.00	0.05	5.04	1.26	3.78	74.9
5b	3.09	0	0.03	3.06	1.40	1.66	54.2
6a	14.80	2.18	0.06	16.92	9.43	7.49	44.2
6b	14.80	0	0.01	14.79	9.25	5.54	37.6

[1] Sewage irrigation denoted by a, tap-water irrigation by b.
[2] Col. 2 + Col. 3 − Col. 4.
[3] Col. 5 − Col. 6.
[4] $\frac{\text{Col. 7}}{\text{Col. 5}} \times 100$.

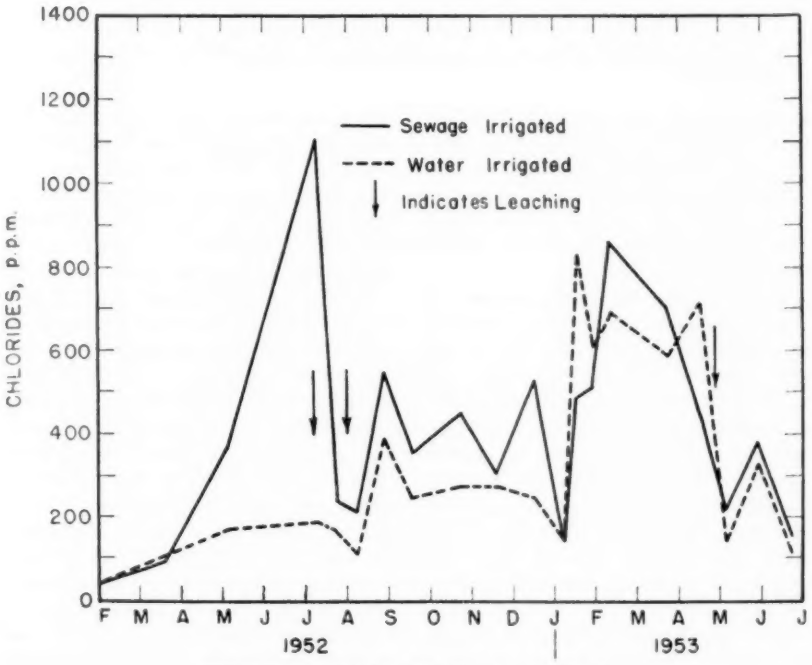

FIGURE 1.—Soluble chlorides in soil No. 1.

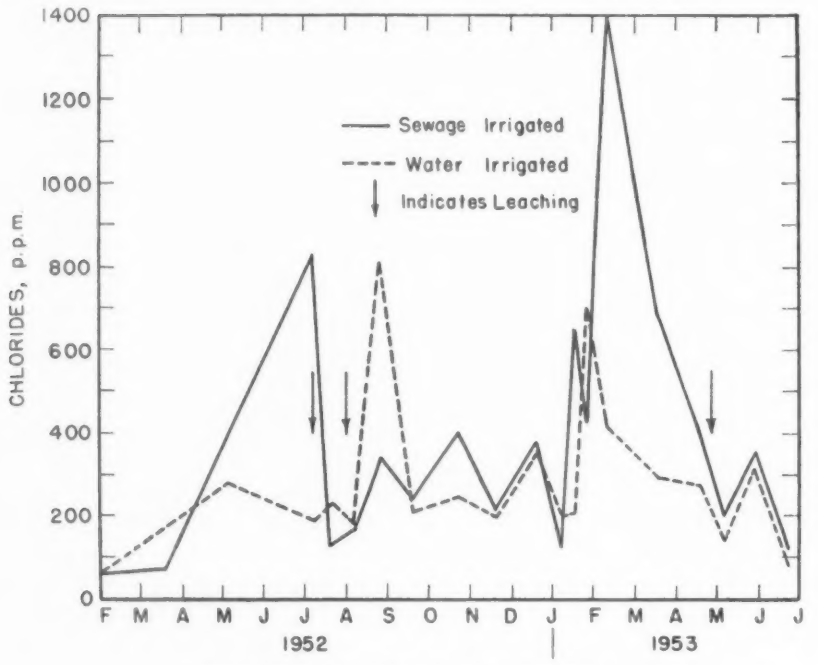

FIGURE 2.—Soluble chlorides in soil No. 2.

of soil used, the amount was 0.362 per cent. These are small amounts, but they may have effects. An application of fertilizer at the rate of 10 tons per acre amounts to only about 0.14 per cent by weight of the top 4 in. of the treated soil.

Table III gives the total amount of organic nitrogen in each pot, based on the values given in Table II, at the beginning and end of the study. It also gives the amounts of organic nitrogen added, and the amounts lost by drainage. Two facts can be noted from the table: although the amount of total volatile solids added to each pot ranges below 0.3 per cent of the weight of the soil in the pot, the amount of organic nitrogen added, with the exception of soil 5, a sand, ranges from 13 to 20 per cent of the total organic nitrogen held by the soil. Yet, the total amount of organic nitrogen held by each pot is less at the end of the test than at the beginning. The amounts lost range from 32.1 per cent (soil 2b) to 74.9 per cent (soil 5a). This loss cannot be accounted for by leaching, as this loss was determined for each irrigation. It can only be explained by denitrification.

According to Robinson (2): "There is also the possibility that nitrates may be transformed by bacterial action into elementary nitrogen. Denitrification, as the process is called, represents a definite loss of nitrogen from the soil. It is the work of a bacterium, *B. denitrificans*, the conditions for whose activity appear to be the presence of large quantities of fresh organic matter and the alternation of aerobic and anaerobic conditions." These conditions apply to the sewage-irrigated soils, which received both water and organic additions; but the tap-water irrigated soil received no organic additions. Of the sewage-irrigated soils,

1a, which had been irrigated with sewage for more than 10 years, lost the lowest percentage of its organic nitrogen (34.6); and 1b, which had received tap water only during the course of the test, lost only 26.7 per cent, less than 1a, and least of all the soils.

Soluble Chlorides

The accumulation of soluble chlorides in soil is to be expected when it is irrigated with sewage. Such accumulation and its leaching was studied. A modification of the method of Piper (1) was used to determine the amount of soluble chlorides in the soil sample. Samples for testing were taken from the top 3 in. of the pot, except at the beginning and end of the study. As already indicated, irrigation, whether with tap water or sewage, proceeded with each pot until sufficient drainage occurred to permit analysis for chlorides and organic nitrogen. At the end of the study the average chloride content of the sewage-irrigated soils was 137 p.p.m., of the water-irrigated soils, 88 p.p.m.

As expected, chlorides built up in the soils (Figures 1 to 6). When they became high their concentration was reduced by irrigation with larger approximately equal amounts of sewage or tap water. Arrows on the figures indicate when leaching with tap water was done. A few comparisons are of interest. Although the applied sewage had a chloride content of 146 p.p.m. and the tap water 54 p.p.m., the rate of accumulation showed no correlation between these two amounts. Behavior of the various soils in the accumulation of chlorides and leaching by irrigation with tap water is related to the type of soil. Soils 1, 2 and 3, the silty clay loams accumulated more chlorides in a given time than the sandy loams and

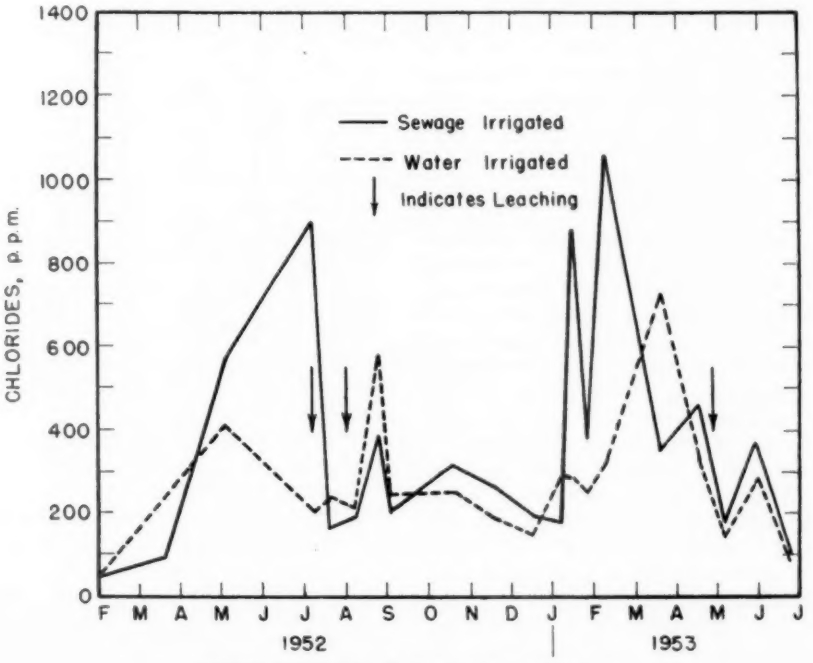

FIGURE 3.—Soluble chlorides in soil No. 3.

TABLE IV.—Comparison of Chlorides in Soils

Soil	Figure	"a" Area[1]	"b" Area[2]	Ratio[3] (%)
1	1	1,810	1,210	149
2	2	1,639	1,149	142
3	3	1,586	1,204	132
4	4	1,123	945	119
5	5	678	624	109
6	6	1,218	964	126

[1] Area under curve for soil irrigated with sewage.

[2] Area under curve for soil irrigated with tap water.

[3] Ratio of a area to b area.

sand. This was established roughly by noting the areas beneath the curves (see Table IV).

The behavior of soil 1, which had long been irrigated, as compared with soil 2, indicates that the longer a soil has been irrigated with sewage the greater is the tendency to accumulate chlorides. This is also shown, in a general way, by the curves of all soils (Figures 1–6). Both the sewage-irrigated and the water-irrigated soils tended to have somewhat higher chlorides in the last six months of the study period. Leaching, however, is sufficiently effective to reduce the chlorides to a non-injurious level.

Water-Retaining Power

One-quart ice cream cartons were used for determining the water-retaining power of the soils. Holes about $\frac{1}{16}$-in. in diameter were punched in the bottom of each and filter paper was placed above them. Each carton was weighed and then filled with a known amount of each soil which had been air-dried and sieved. Water was then added to the extent of its holding capacity. Six such cartons were prepared and tested at the beginning of the study for each of the original soils and twelve were set up for irrigated soils. For each specimen weighings were made to determine the proportion of the water added still held by the soil. At the end of 29 days further loss of water had practically ceased, except for the sandy soil, No. 5, which had lost practically all its water at the end of 17 days.

In general, irrigation under the test conditions, either with sewage or tap water, had no significant effect upon water-retaining capacity. As compared with the capacity of the original soil, irrigation reduced it. This may be ascribed to irrigation in the absence of such factors as tillage and worm action. The percentage of water remaining in the soils after 15 days and 29 days is given in Table V. It will be noted that the irrigated soils in each case retained slightly more moisture at the end of the observation period than did the original soil.

Water-Raising Power

A study was made to determine whether sewage irrigation would affect

TABLE V.—Water Retained in Soil Specimens

Soil[1]	Moisture Retained (%)	
	After 15 Days	After 29 Days
1	28.4	1.6
1a	16.3	3.3
1b	18.4	3.8
2	35.7	3.1
2a	19.5	3.8
2b	18.6	3.0
3	38.2	4.6
3a	22.6	5.5
3b	25.8	7.1
4	30.2	1.5
4a	14.4	2.5
4b	13.2	2.5
5	0.7	—
5a	1.0	—
5b	1.2	—
6	28.1	0.8
6a	16.5	2.6
6b	14.4	2.4

[1] Sewage irrigation denoted by a, tap-water irrigation by b; unlettered designates original soil.

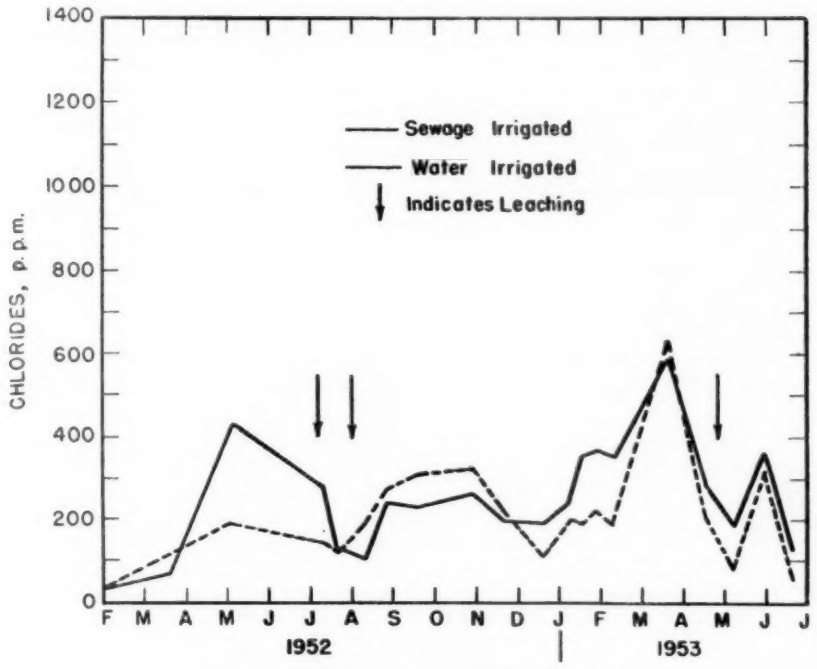

FIGURE 4.—Soluble chlorides in soil No. 4.

the capacity of the soil to raise water from deeper levels toward the surface where vegetation could utilize it.

Glass tubes 4 ft. long with an 1⅞-in. inside diameter were used. The tubes were filled with the soils gradually and compaction was obtained by tapping and rotating the tubes. Each tube was then set up vertically in a beaker of water. The height to which the water had risen in each tube was measured over a period of 30 days.

Except for the sandy soil 5, the data obtained indicate that irrigation with sewage reduces the speed at which water will rise in the soil. Irrigation with tap water resulted in faster rising rates as compared with those of the original soils in some cases, but comparison of the original soil samples in the tubes with the irrigated samples is probably hazardous. More nearly comparable are the two types of irrigated specimens. A typical set of readings is for soil 1, original, sewage-irrigated and water-irrigated at the end of 18 days, when the water had risen 92.9, 82.9, and 93.1 cm., respectively, while for soil 3 the readings were 70.1, 53.8, and 65.8 cm., respectively.

It was thought that the chloride content of the soil might affect speed of rise. It will be remembered that at the end of the study period the average chloride contents of the sewage-irrigated and tap-water-irrigated soils were 137 p.p.m. and 88 p.p.m., respectively. Accordingly, pairs of tubes of soil 2, which is clay loam, and soil 4, which is sandy loam, were prepared. One pair received no addition of chloride; the other pair had 800 p.p.m. of chloride as sodium chloride added. They were then placed in the beakers as already described. The results are striking. In soil 2, with sodium chloride added, the water had risen 21.6 cm. in 4 days, whereas without the

addition the rise had been 39.4 cm. The corresponding values for soil 4 were 26.7 cm. and 54.7 cm. This, of course, is an exaggerated test as, except for the top 3 in., the chloride content of the soils did not reach 800 p.p.m. It appears, however, that chloride accumulations will delay the rise of water in soils.

Pore Space

Pore space influences the fertility of the soil. It facilitates passage of air and moisture and root penetration and is associated with proper crumb structure.

The technique of determination of pore space depends upon the fact that neither benzol nor carbon tetrachloride wet the soil to which either may be added. Hence the voids in a soil sample can be determined by measurement of the amount of either liquid required to fill the voids. A 100-ml. graduate was filled with an air-dried sample that would pass a No. 40 sieve and benzol or carbon tetrachloride was added until the liquid stood above the soil surface. The graduate was gently tapped during the filling. The overlying liquid was measured and subtracted from the total volume added. From this amount the pore space, as a percentage of the volume of the soil sample, was computed (Table VI).

TABLE VI.—Pore Space in Soils

Soil	Pore Space (%)		
	Original	Sewage-Irrigated	Water-Irrigated
1	38.4	38.4	37.2
2	38.6	37.6	37.4
3	39.5	40.1	39.4
4	38.8	40.5	39.4
5	30.2	29.8	29.4
6	40.5	39.9	40.2

In general, the pore space of a soil

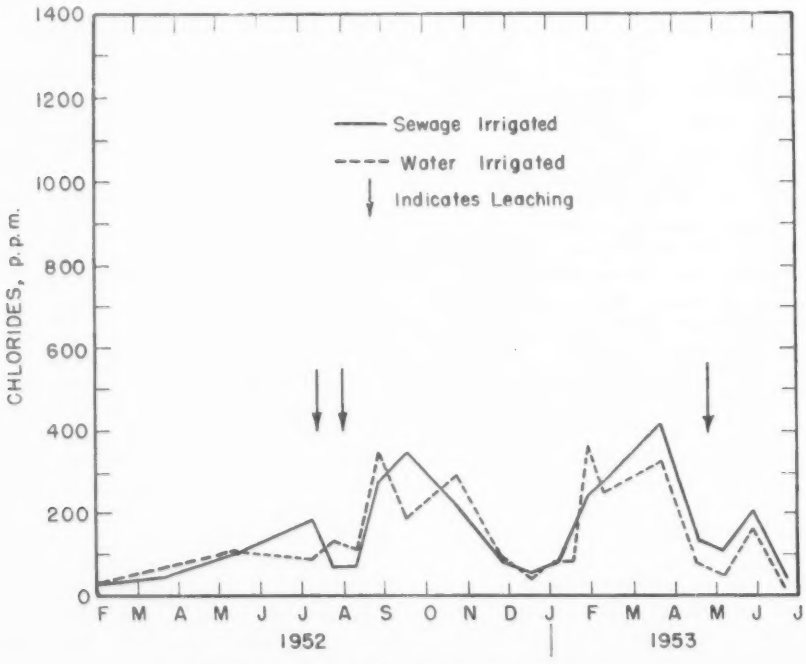

FIGURE 5.—Soluble chlorides in soil No. 5.

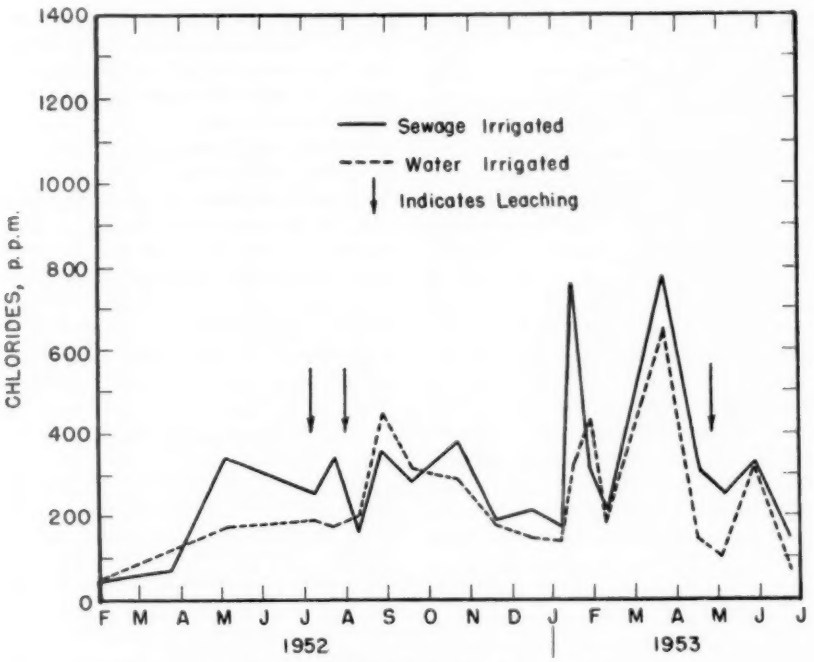

FIGURE 6.—Soluble chlorides in soil No. 6.

depends upon whether it is loose or perhaps temporarily compacted, on the size of the soil particles, and to what extent they are joined into crumbs. The true pore space of a soil can only be determined on a soil when it is in its original position. It should be possible, however, to compare the irrigated soils to determine differences which may have been caused by sewage. From Table VI it appears that irrigation with sewage was beneficial as compared with irrigation with tap water, although the differences are not great. Soil 6, which shows a smaller pore space for sewage irrigation, differs from the other soils in having a large number of small particles of calcium carbonate; unless the number of these particles in the two samples is the same, comparison is difficult.

Crumb Structure

The crumb structure of the soil is that peculiar arrangement of soil particles which holds them together as aggregates. The individual soil particles are held in groups, slightly apart but cohering by the binding of soil colloids or organic matter. There are two types of soil crumbs—false crumbs, which fall apart in contact with water, and true crumbs, which are not affected by water.

Lack of true crumb structure results in a sealing of the earth surface by small particles following a rain or irrigation, whereas a good proportion of true crumbs allows continued entrance of moisture and air.

The method used for determining crumb structure was as follows (1):

1. A sample of air-dried soil, 2 to 4 g., was placed on a weighed No. 60 sieve 3 in. in diameter. The soil sample weight is *a*.

The sieve is immersed with the soil in water, raising, lowering, and shaking until no more soil particles leave the sieve. Sieve and soil are dried and

weighed. The weight of the dry soil is b.

2. The soil is transferred to a 300-ml. beaker and three 20-ml. portions of 5 to 6 per cent hydrogen peroxide are added, warmed slightly, if necessary, to promote action. This is allowed to stand overnight. When all the organic matter is destroyed, as shown by no further formation of bubbles or color change, about 150 ml. of 0.1 N sodium hydroxide are added and the sample is rapidly stirred. The sample is then poured back into the reweighed sieve, and is washed gently with distilled water to remove reagents and disintegrated material. Thereafter the sample is dried and weighed. This weight is c.

3. Weight a is the total amount of soil; b is the weight of the true crumbs plus such adventitious material as small stones and large sand particles; c is the weight of these adventitious particles. The true crumbs in per cent of the dry soil will be $\frac{b-c}{a} \times 100$.

Table VII gives the averaged results of two sets of tests of five different soil types. It will be noted that sewage-irrigated soils 1, 2, and 3 have a greater percentage of true crumbs than their water-irrigated counterparts. Soils 4 and 6 differ from the other three soils in having both a higher sand and a higher calcium carbonate content. Sand decreases the crumb-forming power of a soil. Calcium carbonate soils, it is generally accepted, have a better structure than others, but this is only true if the calcium carbonate is fully disintegrated, which is not the case in soil 6.

TABLE VII.—Crumb Structure of Sewage-Irrigated and Water-Irrigated Soils

Soil	True Crumb Content (%)	
	Sewage-Irrigated	Water-Irrigated
1	9.35	7.88
2	12.66	10.75
3	14.65	10.70
4	6.28	7.18
6	10.40	11.19

Judging by the tests, it appears that irrigation with sewage is beneficial to the crumb structure of silty or loamy soils, as compared with irrigation with water. It will be noted that there is some correlation between effect upon pore space and crumb structure, since the silty loams were also affected more favorably as to pore space by sewage irrigation.

Total Organic Matter

There is as yet no precise and generally accepted method for the determination of soil organic material or humus. Partly this is due to the fact that the decomposition of organic material from the original to the "humus" state is slow and the result of a number of agencies, bacterial and chemical.

Preparation of a sample for humus determination was done in the following manner. The soil to be sampled was crushed to destroy clods and rocks, and leaves and large particles in the original state were removed. The sample was then passed through a No. 40 sieve and quartered. The portion from which the sample was to be taken was then again cleaned of all apparently undecomposed material and the required air-dried sample was then weighed. If humus is defined as decomposed matter, including organic matter in the process of decomposition but which has lost its original structure, Table VIII shows the humus content at the time the test was made.

Table VIII gives the results of humus determinations. It will be noted that sewage irrigation resulted in greater amounts of humus in the soil than when water was used. This ap-

TABLE VIII.—Total Organic Matter (Humus) in the Soils

Soil	Total Organic Matter (%)		
	Original	After Sewage Irrigation	After Water Irrigation
1	3.87	7.72	7.30
2	5.64	7.54	6.62
3	8.02	9.88	9.24
4	4.14	5.83	4.90
5	0.40	0.23	0.31
6	3.56	6.93	6.41

pears to be contradicted, however, by the fact that original soil 1, which is soil 2 that had been irrigated for years, shows less humus than the latter. The only explanation is chance in sampling or an analytical error.

The increase of humus showed by the water-irrigated soils can be explained by the fact that the soils, before they were placed in the pots, were not as carefully cleaned of obvious organic matter as were the tested samples. Therefore, the humus in the water-irrigated samples is that which developed during the study. The significant point is that sewage irrigation resulted in a greater accumulation of humus, except in the very sandy soil.

Field Capacity

Field capacity is defined by Robinson (2) as "the amount of water held in the soil after excess gravitational water has drained away and the rate of downward movement has materially decreased."

To make the test, pint ice cream cartons were used. In the bottoms, 1/8-in. holes were punched; filter paper was fitted over the bottom. The carton was then weighed. Air-dried sieved soil was then placed in the carton, which was gently tapped during the filling process. The weight of the dry soil was then obtained. Water was slowly added until the first drops escaped at the bottom. A top was placed on the carton, which was then placed on a layer of damp soil. After three days each carton was weighed and the amount of water held was determined (Table IX).

The results are not consistent. Three of the sewage-irrigated soils show an increase of field capacity when compared with the water-irrigated soils. Irrigation, in general, except for soil 6, the sandy loam, caused a slight reduction.

Chemical Constituents

The determinations of phosphorus, manganese, iron, and titanium in the original soils were all made by one analyst, but determinations of the irrigated soils were made by another. Results obtained are shown in Table X.

The phosphorus content of the sewage varied from 4 p.p.m. to as high as 9 p.p.m., whereas the tap water contained none. When this is considered, the phosphorus results may appear inconsistent, since some of the water-irrigated soils showed increases and calculations of some of the sewage-irrigated soils showed greater increases than could be expected. This may be explained by Piper's (1) statement (p. 138); "Phosphoric acid . . . is readily extracted by hydrochloric acid, and it is generally supposed that the bulk, if not all, of the soil phosphorus is extracted." Therefore, the increases in phosphorus shown in Table X may be due to increases in extractability.

TABLE IX.—Water in Soils after 3 Days

Soil	Water Content (%)		
	Original	Sewage-Irrigated	Water-Irrigated
1	45.5	47.3	42.4
2	47.2	44.6	45.9
3	62.0	58.4	58.6
4	43.2	40.3	39.4
5	22.7	22.0	20.3
6	41.3	47.0	48.5

TABLE X.—Changes in Certain Chemicals

Soil	Phosphorus, as P_2O_5 (%)			Manganese, as MnO_4 (%)			Iron, as Fe_2O_3 (%)			Titanium, as TiO_2 (%)			Available Boron (p.p.m.)		
	Original Soil	Sewage-Irrigated	Water-Irrigated	Original Soil	Sewage-Irrigated	Water-Irrigated	Original Soil	Sewage-Irrigated	Water-Irrigated	Original Soil	Sewage-Irrigated	Water-Irrigated	Original Soil	Sewage-Irrigated	Water-Irrigated
1	0.051	0.050	0.068	0.192	0.088	0.088	3.15	3.12	3.12	0.012	0.017	0.019	—	3.2	2.8
2	0.036	0.065	0.046	0.202	0.108	0.011	2.81	3.06	3.08	0.016	0.017	0.018	—	2.9	2.0
3	0.067	0.150	0.075	0.408	0.146	0.142	5.01	4.54	4.56	0.012	0.015	0.019	—	1.9	2.0
4	0.123			0.150	0.044	0.044	1.95	1.77	1.78	0.012	0.008	0.008	—	2.2	1.7
5	0.008	0.006	0.014	0.008	0.004	0.004	0.55	0.33	0.34	0.024	0.004	0.004	—	—	—
6	0.103	0.115	0.111	0.192	0.050	0.005	2.72	2.84	3.09	0.012	—	0.012	—	—	—

There is also a general tendency for increased phosphorus in the sewage-irrigated soils over those irrigated with water. It can be concluded that phosphorus is not lost by irrigation. This is indicated by the fact that of soils 1 and 2, the former, which had been long irrigated with sewage, had more phosphorus than soil 2.

The amount of manganese present in a soil is largely influenced by the amount of water present and the activity of soil organisms dependent upon humus and soil aeration. This activity may increase the solubility of manganese and encourage leaching. This would account for the reduction of manganese shown in the sewage-irrigated soils and the greater amounts retained in those which were water-irrigated.

The same tendency can be noted with iron, as with manganese, although it is not so pronounced. The changes in condition of iron (that is, soluble and insoluble) with leaching, are the causes of "hardpan" of clay soils. Such layers were found in both pots of soil 3.

The increases of titanium content in soils 1, 2, and 3 are probably due to the solvent action of the water or sewage, rather than to any titanium in the sewage, as the increases, with one exception, are approximately or exactly the same for each of the soils. Soils 4, 5, and 6 lost titanium. This may be due to their sand content, especially since soil 5, which is almost all sand, had the greatest loss.

Available boron is considered important as a soil constituent. Lack of time prevented boron determinations for more than four of the irrigated soils and on any of the original soils.

As Table X indicates, sewage irrigation resulted in a greater boron content than water irrigation, except for soil 3, where the difference was only 0.1 p.p.m. It is of interest that soil 1, which had long been irrigated, showed an increase over soil 2, which is the

same soil without sewage irrigation. It appears that irrigation with sewage will increase the boron content of a soil.

Exchangeable Cations

It is commonly accepted that a high base (cation) status is a desirable soil characteristic. Such soils, particularly if calcium is abundant, have a better crumb structure and permit better circulation of both air and moisture; the bad effects of tight clay structure are reduced. Apparently there is also less leaching and loss of humus. It is important, therefore, to note the effect of sewage irrigation on the calcium carbonate content of soils. Table XI shows the cations in the soils, expressed as milligram equivalents.

In relation to the exchange of cations in the samples, certain statements by Kelly (3) are of interest. On p. 56, Gedroiz is quoted: "Dilution substantially decreases the power of monovalent cations to replace exchangeable Ca^{++}. . . . Replacing effect of Na ions, as a constituent of irrigation water, will fall off as the concentration of the solution decreases. . . . Very little Na^{+} will be taken up by the soil through exchange for Ca^{++}. On the other hand . . . a very dilute solution of Ca^{++} will effectively replace Na^{+}."

It will be noted in Table XI that the sodium content of the soils, whether irrigated with water or sewage, was reduced. This reduction, according to Gedroiz as previously quoted, can be ascribed, at least in part, to replacement of the sodium by calcium. The calcium loss by irrigation, more with sewage, in three of the four soils, can be explained by the action of soil bacteria in making the calcium soluble and its leaching out.

With regard to magnesium, Gedroiz and Hissink (3) point out that although a high percentage of the total calcium of soils is replaceable, this is not true of either magnesium or potassium. This is borne out by the fact that the magnesium is increased by irrigation, with no important difference between sewage or water. Potassium also increased with irrigation, with some slightly greater accumulations in three of the soils that were sewage-irrigated.

TABLE XI.—Cations in Soils

Soil[1]	Cations (mg. equiv.)				
	Ca	Mg	Na	K	Total
1	33.25	2.27	0.18	0.44	36.14
1a	26.45	2.40	0.29	1.79	30.93
1b	30.72	2.51	0.03	1.62	34.88
2	34.40	2.63	0.14	0.32	37.49
2a	24.76	5.93	0.07	1.43	32.19
2b	26.55	5.92	0.03	1.34	33.84
3	46.39	3.37	0.20	0.30	50.26
3a	48.07	3.74	0.02	1.68	53.51
3b	49.41	3.73	0.06	1.59	54.79
4	21.20	1.97	0.25	0.43	23.85
4a	22.50	1.73	0.02	1.60	25.85
4b	22.12	1.69	0.02	1.65	25.48

[1] Sewage irrigation denoted by a, tap-water irrigation by b; unlettered designates original soil.

Discussion

The value of the study here described would have been increased if more time had been available for it. A longer period for application of sewage to the soils might have eliminated some of the inconsistencies and brought more conclusive results. The small differences developed lead to the conclusion that when sewage is applied to soil, and drainage is adequate, the effects will be neither highly beneficial nor injurious.

There is evidence that denitrification occurs and the proportion lost is less with the water-irrigated samples. This can be ascribed to less bacterial activity in those soils. Soil 1, which had been irrigated for 10 years, lost

less nitrogen than the other sewage-irrigated soils, but it would be unsafe to generalize from this one sample.

Chlorides tend to accumulate in sewage-irrigated soils and this tendency increases as irrigation is continued. The chlorides leached out readily and under the usual natural conditions chlorides should present no difficulty.

Sewage irrigation tended to reduce water-retaining power as compared with the original soils and water-irrigated soils. Sewage-irrigated soils, in all cases, however, retained moisture more tenaciously at the end of the 29-day period of the test. This is an advantage as far as crop growth is concerned.

The test for the water-raising power of soils really indicates the speed of water rise. Sewage irrigation consistently reduces the speed of rise both as compared to the original soils and to the water-irrigated soils. It was established that an increase in chloride content lowers the speed of rise.

All but one of the soils showed an increase of pore space with sewage irrigation as compared with water irrigation, although the difference was slight. This soil characteristic is also related to crumb structure and sewage irrigation was found to be beneficial to a notable extent in three of the five soils tested. The other two soils showed slightly unfavorable results as to crumb structure. One of these also indicated a decrease of pore space.

With one exception the soils showed an increase in organic matter in the sewage-irrigated over the water-irrigated and also of the water-irrigated over the original soils. These determinations were complicated by the humidification of "not-yet humidified" materials originally in the soils. The differences are not large. The exception is the highly sandy soil.

Irrigation with sewage showed no consistent effect upon the field capacity of soils. In four of the six soils field capacity was reduced, while in two soils it was increased.

Phosphorus increased slightly in the sewage-irrigated over the water-irrigated soils. The soil long irrigated with sewage also showed a small increase over the similar soil not so irrigated. Manganese showed a loss by sewage irrigation as compared with original soils, but practically no difference as compared with water irrigation. Iron and titanium showed inconsistent results. Boron, in tests of sewage- and water-irrigated samples of four soils, showed more in the sewage-irrigated soils, with one exception.

In the soils studied, base exchange apparently operated to reduce sodium ions in them. There was not, however, an increase in calcium ions but some decrease, which can be ascribed to bacterial or chemical action making the calcium soluble. In all but one soil the loss was greater in the sewage-irrigated soils. Magnesium in general showed no change, whereas potassium increased, particularly in the sewage-irrigated soils.

Conclusions

The relatively small changes in the soils studied indicate that sewage irrigation is neither especially beneficial nor injurious to soils. A few tendencies can be noted that deserve mention.

Sewage irrigation encourages accumulation of chlorides. These reduce speed of rise of water. Leaching of the chlorides was readily accomplished and there should be no injurious accumulations of chlorides with normal operation of irrigation.

A slight increase of organic matter (humus) can be expected.

Pore space is increased by sewage irrigation; crumb structure also shows some improvement.

Sewage-irrigated soils accumulate slightly more phosphorus than water-

irrigated soils. Boron also will be contributed to soils by sewage.

Acknowledgment

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DISTRIBUTION OF EXPENDITURES FOR NEW SEWAGE WORKS IN 1952

Of the $500,000,000 total spent on new sewage works construction during 1952, $455,000,000 was spent by public and $45,000,000 by private utilities. These figures represent estimates by the Water and Sewerage Industry and Utilities Division, Business and Defense Services Administration, U. S. Department of Commerce, reported in a recent Business Service Bulletin (No. 55).

Of the total, 48.1 per cent represented material, with more than 30 per cent of this material cost being expended on piping materials. Labor costs represented 30.2 per cent of the total expenditures, with overhead, profit, and equipment charges taking another 19.5 per cent. Supplies and small tools took the remaining 2.2 per cent.

Treatment plant construction accounted for $75,000,000 of the expenditure. Of the remaining $425,000,000, about 10 per cent was also in treatment plant costs not possible of separation, the remainder including interceptors, pumping facilities, outfall lines, etc. Major items of cost distribution are given in Table I.

Copies of the complete report are available from the U. S. Department of Commerce, Washington 25, D. C., or from any of the Department's field offices.

TABLE I.—Expenditure per $1,000,000 for Construction of New Sewage Works during 1952 [1]

Item	Expenditures ($1,000)					
	Treatment Plant		Collection and Other		Total	
Labor	—	279.8	—	305.3	—	301.5
Overhead, profit, equip.	—	172.9	—	198.5	—	194.6
Supplies and small tools	—	8.7	—	24.9	—	22.5
Materials	—	538.6	—	471.3	—	481.4
Metal products	121.8	—	126.2	—	125.5	—
Machinery and equip.	258.8	—	50.2	—	81.5	—
Stone, clay, glass prod.	125.6	—	217.0	—	203.3	—
Lumber products	18.6	—	25.2	—	24.2	—
All other	13.8	—	52.7	—	46.9	—
Total	—	1,000.0	—	1,000.0	—	1,000.0

[1] Condensed from Business Service Bulletin No. 55, U. S. Dept. of Commerce (Aug., 1954).

EFFICIENT UTILIZATION OF DIGESTER CAPACITY *

By Philip F. Morgan

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Efficient utilization of sewage sludge digestion capacity is a subject difficult to discuss because there is no general acceptance of the ultimate possible loading and there is no general acceptance of the unit of measure that should be used for establishing the maximum loading. Both the ultimate loading and units used for measuring the loading have become of greater importance as new digestion processes have been developed which allow for higher loading and which make use of the full digester capacity.

At most plants there has been, over the years, a continuous increase in the sewage volume and an even greater increase in the quantity of suspended solids, thus accounting for a significant increase in sludge production. The frequent addition of digestion capacity at existing plants is the direct result of this constantly increasing quantity of raw sludge. In many cases, however, efficient utilization of existing digestion capacity may provide the necessary additional capacity and eliminate the need for an expensive construction program.

Because of the complete lack of any accepted measure of loading, it is difficult to establish the validity of the need for expanded facilities by making comparisons with digester loadings at other plants and with loadings obtained as a result of the development of accelerated digestion methods. For example, the units cubic feet per capita, displacement in days, pounds of volatile solids per cubic foot per day, pounds of total solids per cubic foot per day, pounds of volatile solids per cubic foot per month, and pounds of total solids per cubic foot per month were used to express digester loadings in papers presented by three speakers at the Federation's 1953 meeting in Miami. The results reported in these papers cannot be compared without first translating to a common unit.

Acceptance of a uniform measure of loading would obviously be of benefit to all and the unit "pounds of volatile solids per cubic foot per day" appears to be the most logical. The material undergoing digestion is the volatile fraction of the sludge, so it is the only fraction that is appreciably affecting the loading. The cubic foot unit appears to be already accepted and the time unit of one day is preferable to one month because the data are usually collected on a daily basis, there is no uncertainty as to its length (as there is with the month), and the daily loading rate is a single fractional part of 1 lb. that is easily remembered.

In addition to the loading unit of pounds of volatile solids per cubic foot per day, the displacement period in days can be used to advantage because it indicates the concentration of the raw sludge when it is used in conjunction with loading rates.

For those who wish to use it, the volume unit of cubic feet per capita can be obtained directly from the pounds-per-cubic-foot-per-day loading unit on the basis of the equivalent per capita solids load, the percentage of volatile solids in the raw sludge, and plant removal. Because of the uncertainty of the equivalent contributing

* Presented at 27th Annual Conference, Central States Sewage and Industrial Wastes Assn.; Richmond, Ind.; June 24–26, 1954.

population, the volume unit of cubic feet per capita is not desirable for reporting research studies and is not a reliable measure of loading for operating plants.

Most digesters in operation today were built on the basis of capacity per capita with variations in the required capacity depending partly on the type of sewage treatment and partly on the locally accepted capacity requirements. With the issuance of the "Ten-State" standards (1) there was, for the first time, an attempt to standardize the required per capita digestion capacity but, even more important, there was recognition of the importance of considering the volume and character of the sludge, and the recognition that the per capita design data should only be used where information on raw sludge was not available. It is important, therefore, that accurate information on sludge volume and character be obtained at those plants where operating problems are being encountered and expansion of the digestion facilities is being considered.

It has been shown (2) by pilot-plant studies carried out at the Iowa City sewage treatment plant that digestion can be successfully carried out at a loading which for the 10-month period of operation averaged 0.277 lb. volatile solids per cu. ft. per day (0.46 lb. total solids per cu. ft. per day) and for one month averaged 0.345 lb. per cu. ft. per day (0.59 lb. total solids per cu. ft. per day). The commonly used capacity figure of 3.0 cu. ft. per capita, assuming a per capita solids contribution of 0.17 lb. per day, 85 per cent removal in the treatment plant, and 75 per cent volatile content, is equivalent to a loading of 0.036 lb. per cu. ft. per day. Thus it can be seen that the 10-month average loading rate of the pilot-plant studies was almost eight times the loading rate for a 3-cu. ft. per capita capacity design.

The digestion process employed to secure successful operation at these loading rates consists of a biological digestion unit with continuous recirculation of digester gas through centrally located gas diffusers, which results in complete gasification of the sludge by circulation of the entire contents, thus bringing the seed sludge, the raw sludge, and the gas into intimate contact while maintaining a uniform constant temperature in the entire contents of the unit. If supernatant separation, sludge concentration, and sludge storage are necessary before final disposal, a mechanical phase of liquid separation is required. This phase can be carried on most economically in simple holding tanks, or even in lagoons if properly constructed. Regardless of how it is carried on, it is clearly a mechanical separation phase, not biological, and so is carried on as a separate and second step in the process of disposal of sludge.

The operation of the biological phase with the gas recirculation can be compared to the activated sludge process. The diffusion of gas bubbles near the bottom of the tank results in a uniform lift of the contents over the area of active diffusion and causes a gentle roll of the entire tank contents, with upflow at the tank center and downflow at the periphery. As with the activated sludge process, gas, raw sludge, and seed sludge are intimately mixed for maximum biological activity and the gas provides a most economical means of slowly rolling the entire tank contents.

Model studies have shown that with the center gas diffusion a true roll develops. Therefore, the bottom velocities are substantially the same as the top velocities, and that on a vertical line through the tank, midway between the center and periphery, velocities decrease from a maximum just below the surface to a stagnation point at half the depth and then gradually increase, but in the opposite direction,

to a maximum just off the floor of the tank.

These bottom velocities are important in helping maintain full tank capacity. Sand and other inert materials, which materially reduce the effective size of most digesters after a few years of service, appear to be carried by the bottom velocities to the center of the tank, where they are dropped just under the rising column of gas. If the sludge withdrawal pipe is located at this point, the sand and inert materials are withdrawn as fast as they are deposited and thus the full tank volume remains effective.

The roll of the tank contents also carries floating solids down into the digesting liquor and the problem of scum formation appears to be likewise eliminated.

The operating results of the 1,130-gal. pilot-plant unit for the 10-month period November 12, 1952, to August 30, 1953, are summarized in Table I. Additional details regarding this study have been previously published (2), but the summary data are indicative of the loadings which can be obtained under continuing operating conditions. To provide an adequate factor of safety, it is recommended that until further field data are obtained, full-scale installations be designed for 0.2 lb. of volatile solids per cu. ft. per day. Higher loadings may be utilized at existing plants on the basis of the opportunity for developing an objective loading rate by preliminary operation in one tank.

TABLE I.—Pilot-Plant Operation; Average Results November 12, 1952, to August 31, 1953

Raw sludge:	
Total solids (%)	6.12
Volatile solids (%)	62.7
pH	5.71
Loading:	
Total solids (lb./cu. ft./day)	0.461
Vol. solids (lb./cu. ft./day)	0.277
Displacement (days)	8.7
Gas production:	
Cu. ft./day	346
Cu. ft./lb. vol. sol.	8.85
Operating conditions:	
Digester temp. (°C.)	33.7
pH	6.90
Volatile acids (p.p.m.)	409
Gas recirc. (c.f.m. free gas)	1.89
Digested sludge:	
Total solids (%)	4.60
Volatile solids (%)	47.5

Confirmation of the pilot-plant work has been carried on in full-scale units at Columbus, Ohio (3), and at Erie, Pa., and other units are to be started in the near future.

The results of the pilot-plant work and the confirming full-scale installations have demonstrated that there are potentially real savings which can be made wherever present digestion facilities are inadequate and expansion is contemplated. From the standpoint of the superintendent and the designer, this is most interesting. To those working in the laboratory, however, some of the laboratory studies are even more interesting. The results of laboratory studies on the effect of the rate of gas recirculation and the effect of continuous gas recirculation were presented in an earlier publication (2) and it was shown that digestion could be carried on at high loadings with continuous gas recirculation and that there appeared to be a direct relationship between the quantity of gas recirculated and the time required for stabilization of the digestion process at the higher loadings.

Another series of laboratory studies was undertaken to obtain information on the actual rate of digestion as indictated by gas production rates in relation to the food material added. From observation of conventional digestion units, it was known that the rate of gas production increased immediately following sludge addition, but quantitative data were not available. Furthermore, there has always been the possibility that the rate of gas production is temporarily increased partly as a result of the turbulence induced by pumping the raw sludge into the tank.

This study was undertaken to ob-

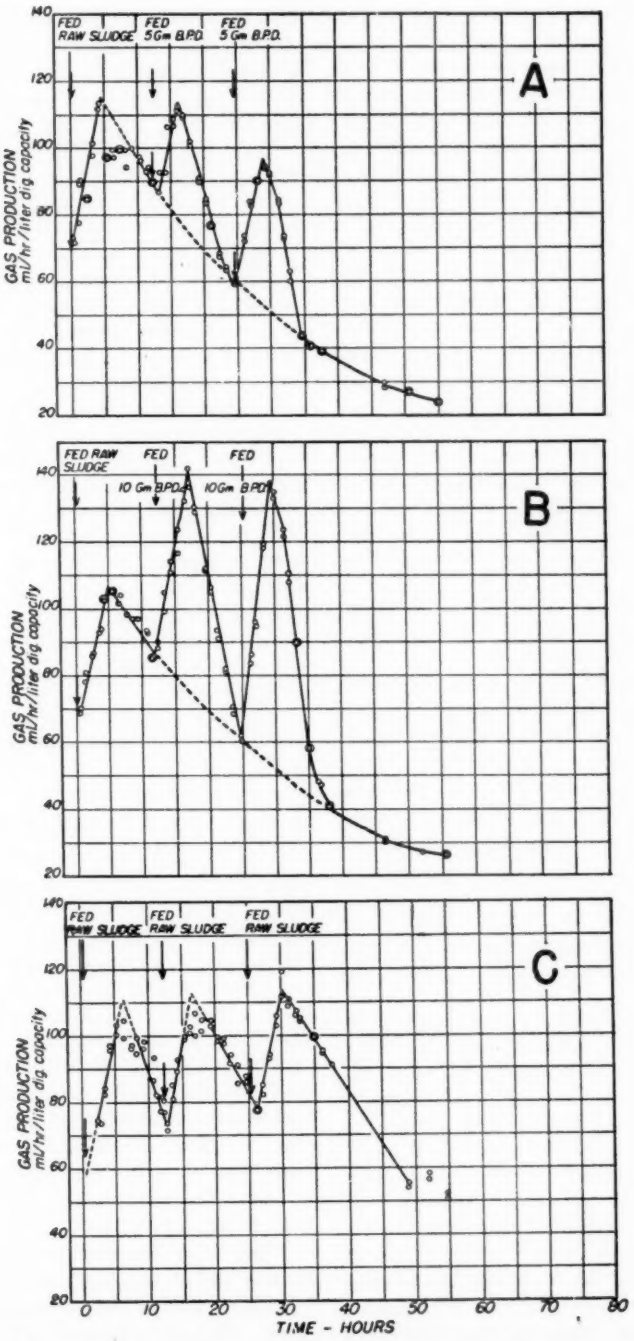

FIGURE 1.—Effect of food additions on gas production and digestion rates in three laboratory digesters operating in parallel. (B.P.D. indicates beef-peptone-dextrose mixture.)

tain quantitative information and to provide information needed for closer control of the digestion process. As in the earlier laboratory studies, the digesters were 8-l. bottles in a 35° C. incubator. Each bottle was equipped with a bottom outlet for withdrawing sludge and top openings for adding sludge, for gas take-off, and with a connection to a porous diffuser for recirculating gas immediately after each feeding. For each run and several hours before the start of the run, each bottle digester was filled with digesting sludge from the pilot plant, and at least one feeding of raw sludge from the Iowa City sludge sampling line. Gas production rates were measured by recording the velocity of movement of a bubble of mercury in a horizontal calibrated glass tube connected to the gas take-off line. During a run, the rate of gas production was measured at frequent intervals and additional sludge or other food was added as required.

A synthetic sludge which was completely uniform and readily available as a food supply was used for some of the runs. It consisted of a 10-g. mixture of bacto beef, bacto peptone, and bacto dextrose (3 parts, 5 parts, and 5 parts by weight, respectively) diluted in water to a volume of 300 ml., and is referred to herein as B.P.D. The quantity of B.P.D. used is recorded in terms of grams of the beef-peptone-dextrose mixture without the water.

Figure 1 shows the results of a typical series of three digesters operating in parallel. Eighteen hours before the start of this run the three bottle digesters each received 6,750 ml. of digesting sludge from the pilot plant and one feeding of 375 ml. of raw sludge (12.9 g. volatile solids). At zero time, all three digesters again received 375 ml. of raw sludge (22.3 g. total solids, 16.3 g. volatile solids). Gas production rates were recorded at frequent intervals. In each case there was a continuous increase in the production rate for about 5 hr. and then a sharp reduction in rate, which continued until additional food was supplied at 12 hr. The time and quantity of food additions are indicated on the figures. The raw sludge added to digester C at 12 hr. and 25 hr. was the same material and the same quantity as that added at zero time.

The resulting curves for digesters A and B indicate that the first feeding of synthetic sludge was completely digested in about 13 hr. The fact that the gas production rate at the end of this 13-hr. period was reduced to the level which would have existed if no additional food had been added is the indication that the synthetic sludge was completely digested and the fact that the gas resulting from the 10-g. feed is almost exactly twice that resulting from a 5-g. feed provides further indication. The gas production from the second synthetic feed at about 25 hr. confirmed the results of the first feed.

At 55 hr. the gas production had about leveled off in digesters A and B, indicating that digestion of the raw sludge added at zero time was substantially complete and although gas production rates for this series were not recorded after 55 hr., other data have been collected which indicate gas production practically stops after three days.

If the gas production rate is a reliable measure of rate of digestion, these studies indicate that, for primary sludge, digestion periods of as short as three days are possible and probable. In order to provide a factor of safety for full-scale installations, six to ten days would be required. The pilot-plant work has confirmed this allowable loading.

Digester C was operated in parallel with A and B, except that it continued to receive 375 ml. of raw sludge each feed. This is equivalent to 0.272 lb.

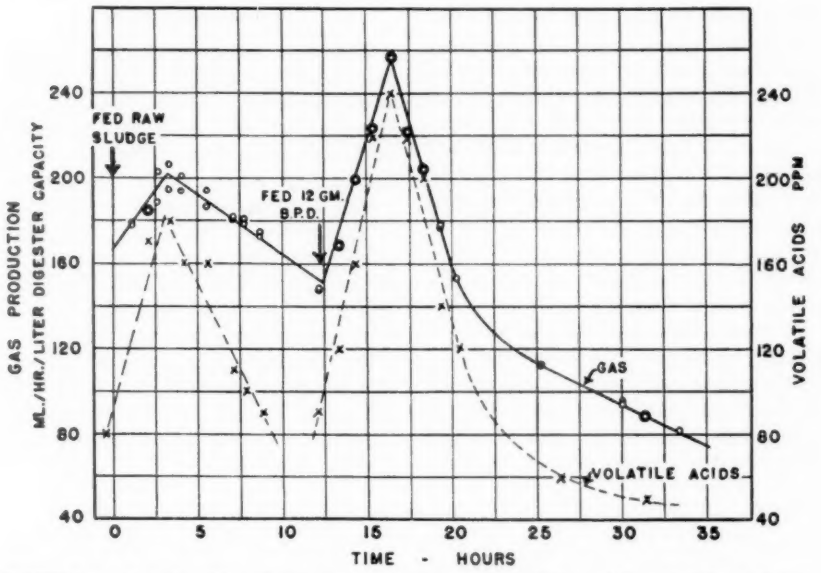

FIGURE 2.—Relationship of gas production rate and volatile acids. (B.P.D. indicates beef-peptone-dextrose mixture.)

volatile solids per cu. ft. per day. The resulting gas production curve is characteristic of that of a normally operating digester with raw sludge being pumped twice a day.

Another series of studies was undertaken to determine the relationship of the volatile acid concentration and the gas production rate in a normally operating digester. The results of this study are shown in Figure 2. For this run, the bottle digester was filled with pilot-plant sludge 18 hr. preceding the start of the run and received one feeding of raw sludge at that time. Then at zero time, 375 ml. of raw sludge was added (20.8 g. volatile solids) and at 12.25 hr. 12 g. of synthetic sludge was added. Gas production rates and volatile acid concentration determinations were made throughout the period of the run. It is apparent from this study that the volatile acid concentration does follow gas production with no lag, another indication that the digestion phenomenon proceeds at a rapid rate, with the maximum rate of volatile acid conversion and gas production following the time of feeding by only 3 to 5 hr.

Conclusions

1. The various units of measure used in reporting digester loadings are discussed and the unit "pounds of volatile solids per cubic foot per day" was recommended as the unit which most nearly measures the true load to the digester. Digestion period, in days, is recommended as a secondary unit of measure to indicate the concentration of the sludge added.

2. If digesters are operated in accordance with the accelerated digestion method, daily loadings of 0.2 lb. volatile solids per cu. ft. are feasible and even higher loadings may be utilized at multiple-tank installations as a result of operating experience in one tank.

3. Laboratory studies presented in-

dicate that the maximum rate of conversion of organic material to gas takes place only 3 to 5 hr. after feeding and that the digestion of raw sludge in this series of studies was substantially completed in 55 hr. Theoretical digestion periods of less than three days should be possible and the proposed loadings, which result in a detention period of seven to ten days, provide an adequate safety factor over the theoretical minimum for raw sludge.

4. Under normal operation, there is a close relationship between gas production rates and volatile acid concentration; thus pointing out the value of the volatile acid determination in the control of the sludge digestion process.

Acknowledgments

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The daily work was supervised and carried on consecutively by Harold E. Schmidt, Edwin D. Simmons, and Peter J. Neuspiel under the author's general direction.

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PROGRESS REPORT ON RAPID B.O.D. DETERMINATION

The prospect of a short B.O.D. test is more encouraging now than ever before, as a result of studies being carried on at the University of Florida by E. R. Hendrickson and George Morgan. The study is sponsored by the National Institutes of Health, USPHS.

Using a suspension of bacteria from a pure culture, the B.O.D. can be calculated from the rate of oxygen utilization per unit time. Massive doses of a single species of a constant age are used to obtain a constant activity, as well as a controllable number of organisms, the latter being determined by the turbidimetric method.

The main effort of the project has been directed toward elimination of as many variables as possible, hence the use of a pure culture in place of activated sludge. The three main divisions of the project are:

1. Determination of the bacterium best suited for the test and study of the effect of varying the number of organisms.

2. Investigation of the oxygen utilization of the bacteria in different types of sewage, including industrial waste as well as sewage from several towns in Florida.

3. Study of the effect of temperature change, thereby determining the optimal temperature for the test.

Indications are that the incubation period for the test can be reduced to one hour.

SEWAGE TREATMENT IN CALIFORNIA STATE INSTITUTIONS *

By Edwin R. Stowell

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The following discussion is on some of the unusual aspects of sewage from state institutions and other facilities of the State of California and how some of the sewage treatment problems have been solved. Specific problems discussed include the treating of salt-water sewage, the use of hillside sprays for disposal of sewage effluent in recreational areas, relieving an overloaded activated sludge plant by installing facilities for leveling out the flow through the plant, emergency storage facilities at small pumping stations, and use of ponds for the treatment and disposal of septic tank effluent.

Sewage Characteristics

The different types of state services or activities requiring sewage facilities are quite varied and include mental hospitals, correctional institutions, state parks, state colleges, state fish hatcheries, Highway Patrol offices, border quarantine and inspection stations, district fairs, forestry camps, and National Guard armories, and many other state activities. From this list it can be seen that the sewage facilities vary in size from that required to serve a few persons to that required to serve one of the larger institutions having a population of 6,000 or more persons and complete with all activities of a small community including laundry, food processing, and some industrial wastes. Obviously, the characteristics of sewage from such a broad range of installations will differ considerably.

The volume of sewage from the state facilities is considerably different from the 80 to 100 g.p.c.d. normally associated with domestic sewage from a community. Over the 5-year period from 1949 to 1954, considerable data have been obtained relating to the volume of sewage to expect from the various types of state installations. These data are used for designing new installations where actual flow data are not available or cannot be made. Sewage flow data for state institutions have been found, in general, to be approximately as follows:

Mental hospitals	—125 g.p.c.d.
Correctional institutions, men	—175–250 g.p.c.d.
Correctional institutions, boys	—150 g.p.c.d.
Correctional institutions, girls	—150 g.p.c.d.
Correctional institutions, women	—150–175 g.p.c.d.

With such high average rates of flow, peak flows might be expected to be relatively low. However, flow measurements show the peak flow rate to be about 2¼ to 3 times the average flow. Minimum sewage flow from institutions has been found to be about 30 per cent of the average flow.

Campers at state parks where showers, laundry, and sanitary facilities are provided contribute about 40 g.p.c.d. Picnickers contribute about 10 gal. per person. Flow from district fairs has been found to be about 6 to 7 gal.

* Presented at 26th Annual Convention, California Sewage and Industrial Wastes Assn.; Sacramento, Calif.; May 5–8, 1954.

per attending person. Although other flow data and methods of expanding average daily per capita flows into design and peak flow rates have been obtained, discussion of these factors is beyond the scope of this paper.

Sewage from the mental hospitals may contain a considerable amount of rags and clothing. The rags, particularly long strips from torn sheets or blankets, can be a terrible nuisance and a definite operating problem. Because of the clothing in the hospital sewage, salvage screens are normally provided so that, where warranted, clothing can be salvaged for re-use. In this regard, in some instances automatic bar screens are not suitable for salvage purposes because the larger materials, such as dresses, are torn.

Silverware and other metal or hard materials are frequently found in mental hospital sewage. Some patients find it entertaining to sit at manholes and drop stones through the cover pull hole. It is interesting to note that this same behavior is exhibited by children at state parks, where gravel and twigs are dropped into the sewers in the same manner.

The prisons likewise have a high proportion of rags, cloth articles, and metal articles. This is particularly noticeable when an inspection is rumored. Then the water closets in the cells become the most convenient means of disposing of any unauthorized items, such as extra towels, socks, or other materials.

Because of the stones, silverware, and other hard objects in mental hospital and prison sewage, use of gravel traps is being considered to protect comminutors or other mechanical equipment at these treatment plants. The type of trap under consideration and included in one of the recent projects consists of a small basin wherein the velocity or turbulence is sufficient to flush out organic matter, but insufficient to carry over silverware or stones.

Several papers could be written on further characteristics of state sewage, such as high laundry loads at mental hospitals due to the daily laundering of bedding and clothing from the so-called untidy patients; or seasonal variations in flow, such as at state parks and district fairs.

Sewer Design

Proper design of sewers is considered very important. A full discussion of this subject, however, also is beyond the scope of this paper. It should be noted, nevertheless, that the State Division of Architecture has prepared a Manual of Design covering what is considered good sewer design practice. Design features adopted include the priming of pipe ends for hot-poured joints, the design for minimum flow conditions as well as at the design flow, the testing of sewers under a hydrostatic head and setting of maximum allowable leakage rates, the design of manholes, the setting of wyes, and other pertinent features.

The only feature discussed further at this point is the testing of sewers under a hydrostatic head. This requirement with a given maximum leakage allowance has been the greatest single factor in improving the workmanship of sewer construction. The requirement in effect makes the contractor a partner in obtaining good watertight construction, rather than depending on rigid and continuous inspection.

Sewage Treatment

Although, as pointed out, some characteristics of sewage from the various state facilities are considerably different from that of a normal community, fundamentally the sewage is domestic in character and the same general treatment processes as used on community wastes are applicable. As an illustration, state facilities utilize 3 activated sludge plants, 3 standard-rate

filters, 16 high-rate filters, and 6 primary treatment plants followed by ponds, sand disposal beds, hillside sprays, or other treatment or disposal. In state practice, as in normal practice, the type of treatment must be carefully selected to suit the given site conditions, the waste characteristics, and the operation to be provided. In general, it is the policy to provide a design giving the greatest over-all economy, consistent with adequate operational provisions and required functional characteristics.

Contrary to the popular conception that funds are unlimited on state projects, the funds for sewage and other projects are carefully budgeted and there is a considerable emphasis on economy. Nevertheless, despite economy being a large factor, state officials have recognized the responsibility of providing adequate sewage treatment and disposal facilities where needed and in most areas the state is setting a good example in disposing of its sewage.

In design of sewage facilities for the state, the designer is in the somewhat unusual position of also being associated with the operation of the completed plant. That is, he is generally called upon to advise and recommend operating procedures and to trouble-shoot any problems which may arise. Operating diagrams are furnished for the treatment plants showing normal operation and the operation with each of the major units out of operation. This close association with the plant operation assists the designer in getting the operator's viewpoint and helps eliminate undesirable features and add desirable features to future designs.

Post-War Construction

With the phenomenal increase in population of the state since World War II, there has been a similar increase in the need and requirements for state institutions and services. The effect of this growth on the sewage treatment facilities of the state agencies is best illustrated by the following statistics. Of the 28 major or more important state-owned treatment facilities, 21 are either new or have had major additions added since 1948, 2 are to be modified in the near future, and 3 are to be abandoned because of city or county programs which have made sewers available. This leaves only two major plants for which extensive additions or modifications are not completed or planned at this time.

In the design of new plants and the modifications of existing facilities, there have been many interesting problems. Some of the problems of more general interest are described herein.

Treatment of Saline Sewage

San Quentin Prison is almost as old as the State of California. The oldest cell block now in use at the prison was constructed in 1853. Since San Francisco Bay borders one side of the prison, wastes always have been piped to the bay in the most expeditious manner from each building or structure. As a result, in 1949 when the initial studies for the construction of a treatment plant were begun, there were 22 outfalls to the bay and at least one more was added before the initial studies were completed.

Salt water is pumped from the bay for use as service water, including the flushing of water closets. There was some concern, therefore, with the effect of the salt water on bacteriological treatment processes. Growths along the polluted bay shore line and the then strong odors along the Berkeley-Oakland water front were pretty strong evidence that bacteria capable of breaking down organic matter in sewage could exist in salt water. However, fresh water also was used at the prison and it was feared that varying salinity resulting from a variable ratio of fresh and salt water might prevent the growth of bacteria. It is well

known that ocean-going ships are cleaned of salt-water growths and barnicles when taken into fresh water for any appreciable length of time. Nevertheless, despite extensive inquiries, it was impossible to obtain any factual information on the bacteriological treatment of saline sewage. Thus, it was decided to make some additional studies before proceeding with any treatment project.

First, studies were made to determine the probable chloride content of the sewage resulting from the combined fresh- and salt-water wastes. This was somewhat complicated by the fact there were 23 outfalls, as previously mentioned. Also, the investigators were badly misled by estimated water consumption figures given by the prison. Water use figures given by the prison, and making suitable allowance for non-sewage water use, indicated the ratio of salt water to fresh water in the sewage should be about 6 to 1; but chloride tests consistently indicated a ratio of about 1 to 1. This mystery was solved when the investigations disclosed that the fresh-water consumption given by the prison as gallons was actually cubic feet.

With this information, a typical sewer with chlorides of from 6,000 to 8,000 p.p.m. was selected. It was then decided to construct a pilot plant to determine if bacteriological treatment was practical. Use of a trickling filter was selected as the type of secondary treatment best suited to the site and to the use of inmate operating personnel. A high-rate type filter was proposed using a recirculation ratio of at least 1 : 1 based on the average flow so as to average out the variations in chloride content. For example, it was concluded the night flow would be appreciably more saline than the day sewage, due to the elimination of fresh-water wastes from the kitchen, laundry, and other sources. However, this night flow was also much less than the day rate and the circulation of filter effluent would tend to level out the variation in salinity.

A pilot plant was constructed by prison inmates, using available materials or items which could be fabricated at the prison. Rock was hand picked from the prison quarry. Provisions were made for regulating the desired flow and recirculation rate, and the plant was operated for about one year using an inmate operator. Incidentally, due to the low flow used, operating a small pilot plant such as this is quite a headache due to rags, clogging of pumps, distribution of sewage on the filter rock, and other operational problems.

Within a week, the filter rock had a slim growth and it was evident that a considerable degree of purification was taking place. The filter did not pond at any time during the time the pilot plant was in operation. Results of B.O.D. tests on the filter effluent and settled filter samples (the pilot plant was run without a final clarifier) were surprisingly good. Results as high as 90 per cent B.O.D. removal were indicated on several runs.

On the basis of the pilot-plant studies, the state constructed an intermediate-type high-rate trickling filter at San Quentin. Actual plant operation has borne out the pilot studies that sewage with a normal salinity of 6,000 to 8,000 p.p.m. chlorides and variation of the chloride content during parts of the day can be treated by a high-rate filter with recirculation.

There was some thought that sludge from the treatment plant would contain too high a sodium ratio or chloride content to be usable for fertilizer. It is well known that certain plants are injured when the sodium exceeds 75 per cent of all the positive ions. In such a case, the sludge would have had to be used for fill or elutriated with fresh water to remove the excess salts. Tests made, however, by adding the sludge to distilled water and then analyzing the resulting decanted water

FIGURE 1.—Hillside sprays using standard filter nozzles dispose of state park sewage effluent cheaply and effectively.

showed that the sodium ratio does not exceed about 60 per cent. The chlorides also were within the allowable range. This test seems to duplicate the action in adding fertilizer to the soil and then irrigating to leach it down. As practical evidence that the sludge is not fatal to grass, the area where the sludge was piled at San Quentin before grinding and sacking had a growth of grass in late January approximately seven to nine times as high as grass on adjacent areas where no sludge was piled.

Use of Hillside Sprays

In the design of treatment facilities in some of the state parks, the discharge of sewage effluent to the streams or watercourses is frequently not compatible with the recreational use of the area. In three such areas, hillside spray systems have been installed for the disposal of sewage effluent. These installations have proven successful beyond expectations and offer a solution for the economical land disposal of effluent during summer or dry-weather periods.

Spraying is merely a means of distributing the effluent on the land and the hillside designation of the process relates only to the requirement of sufficient slope to distribute the effluent without ponding and puddling.

For spraying the effluent, a standard tricking filter type nozzle is used. This type nozzle has large clearances, thus giving non-clog characteristics and low discharge head requirements. The nozzle used throws a 20-ft. spray under 6-ft. head.

In laying out a hillside system, sufficient spray nozzles normally are provided so that at least one-half of the spray areas can be out of service and resting. The nozzles are spaced so that the sprays do not overlap and so that the theoretical projected downhill wetted area below the sprays will be a diverging area rather than a converging area. Since water running downhill follows a path at right angles to the contours, the downhill wetted area is readily determined for design purposes and the layout of nozzles can be properly set. If the nozzles were set so that a converging wetted area would result, the effluent would tend to collect together and run off from the disposal area.

The actual design of the hillside disposal area is based on application of effluent on the allowable theoretical downhill wetted area at a rate not to exceed 10,000 g.p.a.d. based on the

total number of nozzles. This value has been somewhat arbitrarily taken as the amount of water which could be disposed of by transpiration, evaporation, and minimum seepage. This rate of dosing is equivalent to a little more than 2 in. per week of applied effluent and is about what a good lawn requires in a dry area. It should be borne in mind that the hillside spray systems are at state parks, where the sewage load occurs in the dry season.

In checking the operation of the state systems, at no time has any surface flow of sewage been observed. As each of the installations has certain design features of interest, the three systems will be briefly described.

Taylor State Park

The hillside spray system at Samuel P. Taylor State Park, in Marin County, is located on a narrow ridge. The ridge is forested with redwood trees and a humus layer several inches thick carpets the ground. This humus is considered beneficial in the operation of the spray system, as it acts as a blotter to absorb and distribute the effluent. Due to its textured surface, the surface area of the humus is probably several times the plane area of the ground and it is thought the evaporation may approximate that from a free water surface. It is known, for example, that the evaporation from a saturated sand with its large surface area is greater than from a free water surface.

Because of the narrow ridge and steep slope, it was necessary to provide three levels of sprays in order to provide the required disposal area. Since it might be necessary to operate a portion of the sprays on different levels at the same time, some means had to be provided to maintain the same head on the different spray lines. This was done by providing standpipes at each level in which a constant water level was maintained by use of float valves. The spray lines then were connected to these constant-head tanks, with each nozzle designed for 6-ft. head, making suitable allowance for head losses.

Portola State Park

Portola State Park, west of Palo Alto, is located in a redwood area somewhat similar to Taylor Park, except that the terrain is not as steep and a greater spray area is available. Suitable spray disposal areas existed both below and above the treatment facilities, thus permitting the development of a gravity spray disposal system as well as a pumped system. To dose the gravity system, a dosing siphon was installed in the pump sump for the pumped system, the siphon discharge level being set slightly higher than the pumping level. Thus, the pumped hillside spray system, which is more remote from the river, is normally to be used, but in case of need or in case of power failure, the level in the sump would continue to rise until the siphon discharges to the gravity spray system. Thus, in the event of power failure the disposal of the effluent is automatically taken care of.

Calaveras Big Trees Park

The disposal system at Calaveras Big Trees State Park, in Calaveras County, until recently consisted of a septic tank and a series of shallow leaching boxes. Increased park usage in the postwar years resulted in failure of the leaching boxes to absorb and dispose of the septic tank effluent, and in runoff of effluent to the local watercourse.

Although an isolated hillside overlooking the septic tank had a considerable outcropping of rock and apparently very little soil cover or humus, it was determined to try the use of hillside sprays. There also were considerable misgivings regarding the spraying of septic tank effluent in the area and it was felt that chlorination of the effluent might be necessary to control odors. However, experience with this system during the latter part

of the summer of 1953 was encouraging. There were no odors outside the immediate spray area and the effluent was disposed of without any runoff from the area.

Since this park is in the winter sports area, it also has a winter usage. It is felt, however, that the spray system is not suitable for winter use due to runoff in wet weather and possible freezing during cold weather. Also, sprayed effluent might freeze and accumulate on the hillside and then be released in rather high concentrations during thawing periods.

Fortunately, however, the winter sewage load is considerably less than the summer load and the old leaching boxes are adequate to dispose of the winter sewage. Therefore, there were incorporated in the design provisions for using the leaching system in winter and the hillside spray system in summer.

This septic tank-hillside spray sewage disposal system is inexpensive and may well prove to be the solution to the sewage problem in many recreational areas.

Modification of Overloaded Plant

In the expansion and modification of existing treatment facilities, the engineer often is faced with greater difficulties than are encountered in the design of a new plant. In such design he must make maximum utilization of existing facilities insofar as possible and still develop an economical, coordinated, and integrated treatment layout. Of the several state-owned treatment plants expanded in the past few years, the one at the Chino State Prison serves as a good example of how the desired result can be economically and effectively accomplished.

This activated sludge plant, constructed in 1931, was in excellent physical and functional condition except that the treatment process was completely destroyed by daily peak flows of strong sewage. To maintain the activated sludge and keep the plant in operation, a large portion of the sewage flow was by-passed for several hours each day. Obviously this was an intolerable condition and modification of the plant was necessary.

Since all units of the plant were badly overloaded both organically and hydraulically for a period of possibly 8 hr. a day, there was some discussion of constructing parallel units to expand the plant. This would have been an expensive solution, however, so further consideration was given the problem. From observation of the flow diagrams, it was obvious that although the plant was badly overloaded for a portion of the day, it was also underloaded for a period of 12 hr. or more during the night. The average daily flow was found to be less than the functional plant capacity. Reasoning that the bacteriological process might work better on a steady flow and that the average flow was within the computed plant capacity, ways were considered to level out the flow to the plant. With this in mind, the plant expansion was designed to include a holding pond for automatically storing primary clarifier effluent in excess of the plant capacity and releasing the stored flow to the aerator basins when normal flow was less than the plant capacity so as to try to hold the flow following the primary clarifier to a constant.

Since it is probable that septic conditions and a grass problem would result if wastes were stored and drained from a holding pond on a daily cycle, and since any such septic conditions would be extremely detrimental to the operation of the activated sludge process, the holding pond was constructed as a permanent pond of 2.5-ft. minimum depth and 1 ft. of depth was provided for storage purposes. The pond area was designed on the basis of the daily B.O.D. addition and removal. This has worked very well. The only

noticeable effect on the activated sludge process has been the imparting of a clear greenish color to the activated sludge effluent during periods of greater algae activity. This green color does not appear to be algae or algae remains broken up by the aerators, but rather appears to be a dissolved coloring or chlorophyl from the broken up algae, which are apparently swept out by the activated sludge.

Flow diagrams show that leveling of the flow through the activated sludge treatment facilities has been accomplished and the plant effectively treats the total volume of sewage from the prison.

Emergency Storage at Small Pumping Stations

In Sacramento, where sewage from areas outside the city limits may be pumped to the city sewer system, it is required to supply storage facilities for 24-hr. flow so that no flow is discharged during times of high sewage flow in the city system. Likewise, such storage facilities might be desirable at pumping stations in critical areas when no stand-by service is provided.

Such storage basins are generally expensive, since the live storage area should be below the sewers, which in turn are normally fairly deep at a pumping station. Also, these storage basins are difficult to properly clean and occasionally are a source of odors.

In the design of the pumping station at the Northern California Reception Center near Sacramento, it was necessary to provide such emergency storage. In considering this problem, the underground storage of natural gas using lengths of pipe was noted and it was decided to use a similar scheme. As designed, the storage basin, consisting of approximately 300 ft. of 36-in. pipe, automatically goes into use when the pumps are stopped and automatically drains when the pumps are started. With the pumps in operation the basin will be somewhat self-cleaning, because it drains. However, a manhole was placed on its end so that the storage pipe can be cleaned by flushing with a fire hose.

Estimates indicate that this means of storing the sewage cost only about 50 to 65 per cent as much as a conventional storage basin and will be much simpler to maintain.

Septic Tanks and Ponds

Ponds for the secondary treatment of septic tank effluent have been found to be both economical and free of nuisance when properly designed. As a rule of thumb, ponds are considered suitable in locations with 200 or more sunny days per year. Ponds have been found to be the most feasible means of waste disposal or secondary treatment, site conditions permitting, when use of a septic tank is indicated and soil conditions prohibit the economical use of leaching lines or pits. Such a system will normally have an overflow, particularly in winter; however, the State Health Department has generally accepted ponding for 30 days as equivalent to bactericidal treatment.

In the design of such systems, the sewage is introduced through multiple inlets at the bottom of the pond so as to diffuse the septic sewage through a layer of partially oxidized material and increase the mixing with pond waters before coming to the surface, thus minimizing the chances of odors. Pond loadings are normally based on 50 lb. of available oxygen per acre of pond surface based on ponds 3 to 4 ft. deep. The pond effluent is drawn from the top, which contains the most oxygen. Ponds are provided in duplicate to permit maintenance or even in triplicate when necessary to maintain a long detention period even with one pond out of operation.

Industrial Wastes

PHARMACEUTICAL WASTE DISPOSAL *

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Although penicillin was discovered in 1928, it was not until shortly after the beginning of World War II that the pharmaceutical industry in the United States underwent a major expansion as scientists responded to the discovery that penicillin was an effective anti-bacterial agent for some of the important diseases produced by pathogenic organisms. After acquiring an existing small drug firm in March 1943, the newly formed Bristol Laboratories by September 1943 was one of the 23 pioneers rapidly expanding their penicillin fermentation processes.

Construction of the present plant was started immediately and the company gradually moved from the old buildings to its new location. By early 1954 approximately 900 people were working at the plant, which consists of 22 large buildings housing the production, research, engineering, development, maintenance, and pilot-plant departments.

Source and Characteristics of Waste

As might be expected with a fermentation plant of this size and nature, there are waste disposal problems requiring considerable attention and study. The waste products from the plant are not treated biologically at the plant; however, they are discharged to a county sewer system served by an activated sludge sewage treatment plant. With a treatment system of this type close cooperation with the treatment plant is essential to insure that the factors having an effect on the sewage treatment process are given top consideration.

A complete industrial waste disposal program might consist of volume reduction, strength reduction, segregation, equalization, neutralization, filtration or sedimentation, and chemical or biological treatment. The treatment facilities of the manufacturing plant are limited, however, to the preliminary stages necessary for biological treatment; namely, equalization, strength and volume reduction, and neutralization.

Since penicillin is one of the more common antibiotics produced, it might be well to briefly review the manufacturing process so as to provide a general picture of a fermentation procedure and the related waste products.

In the early days of penicillin production, the mold was grown on the surface of ½ to ¾ in. of a quiescent nutrient solution in flasks, bottles, or trays. A common practice was to use bottles of approximately 2-qt. capacity and to incubate them on their sides to obtain the greatest amount of culture surface. In some industrial plants, as many as 30,000 bottles were inoculated each day, with the plants operating on a 6- to 10-day schedule.

* Presented at 1954 Spring Meeting, New York Sewage and Industrial Wastes Assn.; Syracuse, N. Y.; June 14–15, 1954.

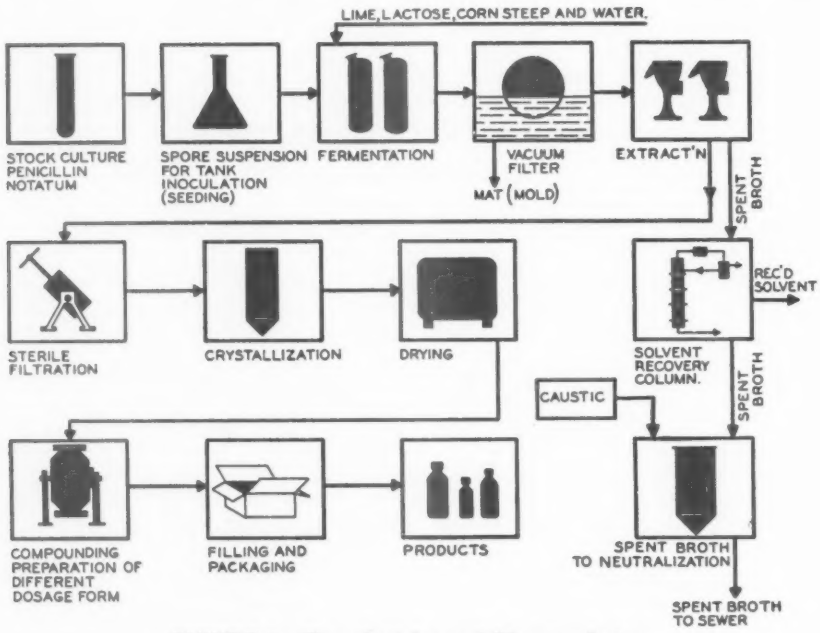

FIGURE 1.—Flow sheet for penicillin manufacture.

The surface culture method has since been outmoded by the submerged, or tank process, which is now employed by Bristol Laboratories. The latter method consists of the steps shown in Figure 1.

The seed for the fermentation tanks is obtained daily from the laboratory, where a master culture of the mold is retained in test tubes. From the master culture larger quantities of the mold are grown in laboratory flasks, which in turn serve as a seed source for the fermentation tanks.

In the fermentation tanks, which stand three stories high, corn steep liquor, lactose, and mineral salts are mixed with water to form a medium which is sterilized by heat prior to inoculation. The inoculum, or seed, of penicillin is added to these tanks and incubated at room temperature for approximately three days under conditions of strong aeration and agitation. By the end of this period, the mold has excreted a material which later is refined and concentrated into the finished penicillin. The liquid, which contains the penicillin, is separated from the residue by the process of filtration. The residue, or mat, may be buried, used as a fertilizer, or dried and used as an animal feed supplement.

The liquid, or filtered broth, from the fermentation process is successively extracted with solvents to dissolve and concentrate the penicillin and eliminate impurities. The spent broth from the extraction process is passed through a solvent recovery column before being neutralized and discharged to the sewer at a controlled rate.

The penicillin is then made pure and sterile by filtering through a special filter to remove fever-producing substances and bacteria. This and subsequent operations are carried out under ultraviolet light in air- and temperature-regulated areas under completely sterile and rigidly controlled conditions.

Following sterile filtration, the penicillin crystals are formed again in their purest state, dried, blended, and compounded with various ingredients to form the final products, which are sent to the filling and packaging department.

Numerous investigations have shown that penicillin wastes are a composite of solids, spent broth, chemicals, and wash and cooling waters. Spent penicillin broth contains sugars, protein, and organic acids. Effective treatment for the removal of solvents and mycelia will generally result in a broth effluent with B.O.D. ranging from 4,000 to 13,000 p.p.m. (1). The strength of a spent broth discharge is dependent upon the amount of food remaining at the end of the fermentation cycle, the efficiency of solvent recovery, and whether or not the mycelia are removed before discharge to the sewer. Brown and Niedercorn (1) have also reported that the process waters from a penicillin plant, including spillage and washings from centrifuges, tanks, filters, stills, and floors, may be expected to have B.O.D. values in the range from 500 to 1,500 p.p.m. The chemical wastes generally consist of acids, bases, salts, and solvents, all of which contribute to the general waste disposal picture.

Industrial Waste Surveys

The first three industrial waste surveys at Bristol Laboratories were made in 1947, 1948, and 1949. The data were obtained by making flow and B.O.D. determinations every 30 min. The B.O.D. values were determined in the company's control laboratory, with the accuracy of the determinations being periodically corroborated by running duplicates at the county sewage treatment plant.

Figure 2 represents the relative population equivalent values per gallon of waste discharged on the dates indicated. This curve is an excellent illustration of what may be accomplished in the line of industrial waste equalization and strength reduction. When the data from the waste surveys during 1947 and the first part of 1948 had been compiled, it was realized that the waste disposal problem was of sufficient magnitude to require a concentrated study. There was a considerable variation in the relative population equivalent until August 11, 1948, with values ranging from a low of 0.37

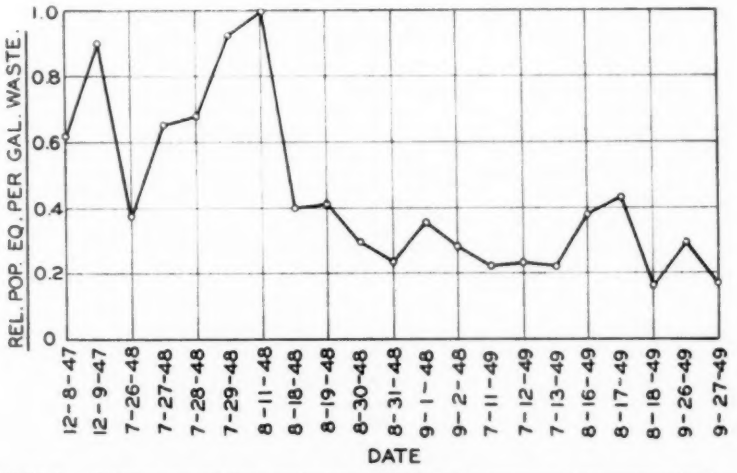

FIGURE 2.—Relative population equivalent of Bristol Laboratory (pharmaceutical) waste.

to a high of 1.0 per gallon of effluent. At first it was thought that the faulty operation of the spent broth solvent recovery column was responsible for the relatively high population equivalent average and range; however, further investigation revealed that this was not necessarily the case. A study of the spent broth data (Figure 3) from the solvent recovery system and the total waste data for the corresponding dates did not reveal a significant correlation. On the basis of these results it was decided that one of the main waste disposal problems was to locate the sources and reasons for the sporadic discharging of wastes within the plant.

Equalization of Wastes

Due to the nature of the penicillin extraction process, the waste disposal problem was not as severe as it might have been. Instead of discharging the spent penicillin broth in batches as large as 20,000 gal. within a relatively short period, the extraction process was such that it was possible to control the waste broth discharge at a rate of approximately 30 to 40 g.p.m. The result was an equalized flow, which provided an effluent much more suitable for biological treatment. The importance of this phase is more readily understood when it is realized that the equalized flow contributes about 40 per cent of the total waste loading.

As shown by the waste surveys, there were also equalization problems over and above that of the spent broth discharge. For example, two of the main factors affecting the strength and volume of the waste were the occasional uncontrolled discharge of spoiled whole broth and various water solutions containing organic solvents known to have extremely high B.O.D. values. The spoiled spent broth problem was reduced in importance by equalization, or limiting the discharge rate to a value which would provide a waste load approximately equivalent to a normal spent broth stream.

From the standpoint of water-solvent solutions it was necessary to attack the problem from two separate angles. The first, that of solvent recovery, is discussed later in this paper. The second aspect of the problem was

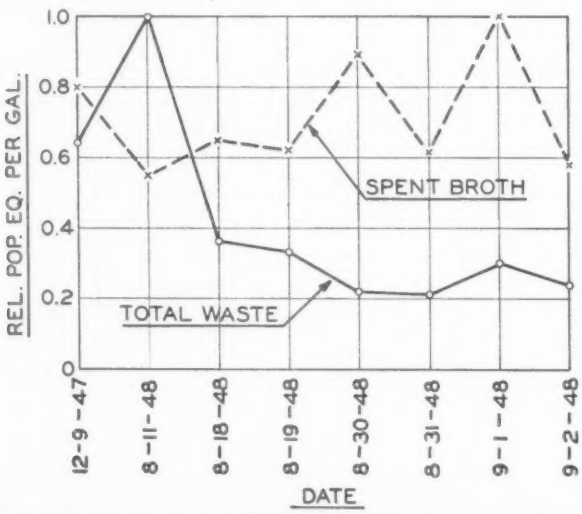

FIGURE 3.—Relative population equivalents for spent broth and total waste.

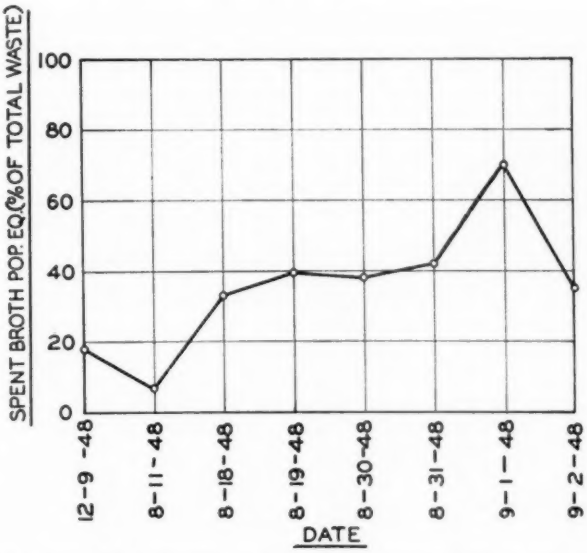

FIGURE 4.—Spent broth population equivalent (as percentage of total waste load).

approached by inaugurating an indoctrination course emphasizing the importance of industrial waste disposal to all personnel from the operating level to production management. Once it was realized that the uncontrolled discharge of solutions containing solvents could lead to serious operating problems at the sewage treatment plant, the problem was on the way toward being alleviated. Wherever possible, the waste solvent solutions were discharged at equalized rates.

The effect of this program is best illustrated by Figure 2, which shows that prior to August 18, 1948, 67 per cent of the relative population equivalent values were only within 0.22 relative population equivalents of the average, with a range from 0.37 to 1.00; the corresponding deviation from August 18, 1948, through September 27, 1949, was 0.09, while the minimum and maximum values were 0.16 and 0.43, respectively. In other words, the variation in strength of the waste had been reduced by approximately 60 per cent.

Strength Reduction

Solvent Recovery

In conjunction with the program to equalize the waste flow to the sewer system, an intensive effort was made to recover solvents wherever possible. The effect of this project is also illustrated in Figure 2, where it may be observed that there was a decided drop in the population equivalent after August 11, 1948. Through August 11, the average relative population equivalent per gallon of waste was 0.74, as compared with a value of 0.29 for the samples taken during the period from August 18, 1948, through September 27, 1949. The reduction in this case amounted to 61 per cent.

The effect of the over-all strength reduction program is further illustrated by Figure 4, in which the population equivalent values of the spent broth are presented as a percentage of the total wasteload. Through August 11, 1948, the spent broth contributed about 7 to 18 per cent of the total waste load. Following the industrial

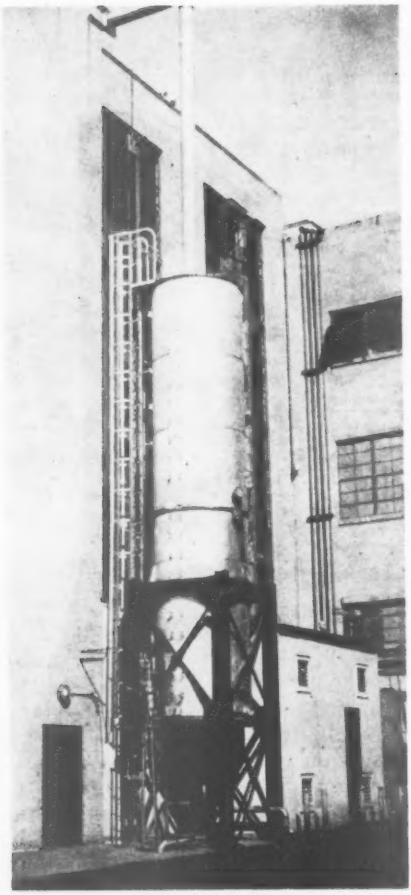

FIGURE 5.—Stripping column for recovery of solvent from spent broth.

waste program, this value had been increased to approximately 40 per cent. Since there had been no appreciable change in the population equivalent of the spent broth during this period, it was concluded that the reductions in the strength of the waste were due to improved housekeeping and solvent recovery throughout the plant.

The solvents used at the plant are normally recovered in either of two systems. First, the solvent remaining in the extracted broth is recovered by passing the broth through a 72-in., 30-ft. high stripping column (Figure 5). In this process, the solvent is removed from the spent broth by passing the broth down through a series of plates and bubble caps to the bottom of the tower, where live steam is introduced. The distillate flowing from the top of the tower is condensed to recover the solvent, while the spent broth is discharged from the bottom of the tower. With this stripping unit it is possible to remove all of the solvent from the spent broth, thereby effecting an appreciable reduction in the waste loading as well as a considerable saving on solvent expenditures.

The second system for recovering

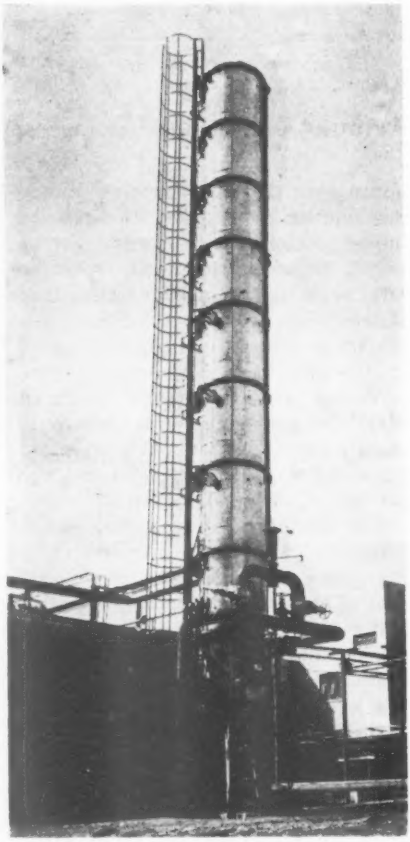

FIGURE 6.—Combined stripping and rectifying column for purifying recovered solvent.

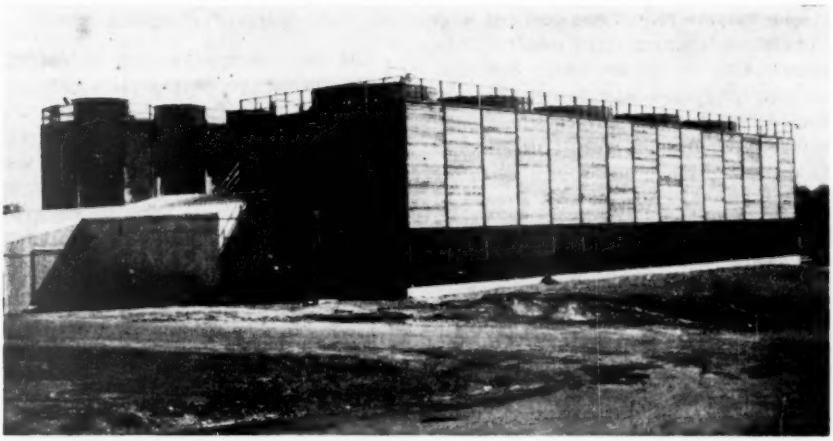

FIGURE 7.—Cooling tower system for re-use of plant process cooling water.

solvents is a combined stripping and rectifying column (Figure 6), with which it is possible to remove all but approximately 0.25 per cent of the water from the used solvent. Dilute solvent solutions, at one time discarded, are now sent to the recovery column, from which the recovered solvents are returned to the respective processes.

Mat Removal

In the penicillin process flow sheet (Figure 1) the mat is removed from the whole broth following the fermentation cycle and prior to extraction. The removal is accomplished by vacuum filtration; the relatively dry mat from this process may be buried, utilized as a fertilizer, or utilized as an animal feed supplement.

Volume Reduction

Volume reduction is another important factor in the waste disposal program. The most effective installation in the plant from the standpoint of volume reduction is the cooling tower system (Figure 7), which eliminates practically all need for city-water cooling systems, the effluents from which eventually would be discharged to the sewer system. At present, approximately 40,000 g.p.d. of city water are required for the cooling tower make-up feed. Without this tower system, about 2.0 m.g.d. of city water would be required to effect the cooling necessary for the various processes and utility equipment. In other words, without a cooling tower system, the volume of the waste effluent would be increased by approximately 2 m.g.d., or 300 per cent.

Since 1949 several water consumption surveys have been made at the plant with the main objectives of reducing the amount of city water used and the volume of the industrial waste effluent. Some of the major points of volume reduction discovered as a result of these surveys are presented in Table I.

TABLE I.—Examples of Waste Volume Reduction in Pharmaceutical Production

Location	Volume Reduction (g.p.m.)
Air cond. condensers	50
Vacuum pump cooling	20
Nash pumps	25
Vacuum ejectors	65
Bleed steam condensation	200
Total	360

The volume reductions realized with the air conditioning units resulted from conversions to tower water for condensing purposes, and the cleaning of fouled heat transfer surfaces on evaporative-type units to result in reduced quantities of make-up water. With the pumps and ejectors, it was a case of converting from city water to tower water for cooling and condensing, respectively. The quantity of water required for steam bleed condensation was reduced by installing control valves on the condensing water headers leading to the various bleeds used for sterilization purposes.

Neutralization

Some of the process waste waters are acidic and some are basic. Wherever possible these wastes are combined to effect a neutralization before discharging them to the sewer system. In some cases, where sufficient basic wastes are not available for combining with acidic effluents, it is necessary to neutralize with sodium hydroxide. This is accomplished through the application of an automatic pH recorder controller unit whereby the pH of the effluent is raised to 4.5 in a continuous-flow system.

Current Program

The last comprehensive industrial waste survey at Bristol Laboratories was made in 1949; however, the overall waste disposal problem has been under constant surveilance during the interim period and at present there is in operation a Waste Disposal Control Center, which authorizes and regulates the discharge of all waste products to the sewer system.

At the time of the 1949 survey penicillin was the main product at Bristol Laboratories. By 1954, however, a good share of the penicillin capacity had been converted for the production of other products, among which are streptomycin and tetracycline. Since the manufacturing processes for these products is somewhat similar to that for penicillin, the waste products are of a parallel nature, but of lower strength, as pointed out by Brown and Niedercorn (1) and Hilgart (2).

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TREATMENT OF MACHINE SHOP AND FOUNDRY WASTES *

By C. W. Hathaway and R. E. Harvie

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Chevrolet manufacturing facilities on the Niagara River at Tonawanda, N. Y., consist of an automobile engine plant, a forge plant, and a foundry. There is also, on adjacent property, a government-owned plant operated by Chevrolet for the manufacture of aircraft engines. The expansion program currently in progress has necessitated additions to previously installed waste treatment facilities and construction of new treatment plants.

The principal liquid waste resulting from the operations in the aviation engine plant, the automobile engine plant, and the forge plant is oil. The principal waste from the foundry is a black slurry resulting from the operation of a sand reclamation system.

The waste treatment systems for these respective operations are discussed separately.

Aviation Engine Plant

Oil wastes from the aviation engine plant are of both the emulsified and the floating type. The emulsified oils result from the discard of cutting and grinding coolants, the cleaning of engine parts, and the scrubbing of test cells. Oils of the floating type result from the leaking of hydraulic equipment and the loss of quench oils and lubricants.

Previous to the installation of the present equipment all waste water containing oil was passed through gravity-type oil separators. These have been retained in the present set-up. Effluent from the separators is pumped to a 15,000-gal. overhead holding tank, from which the water flows to a system designed to treat 3,000 g.p.h.

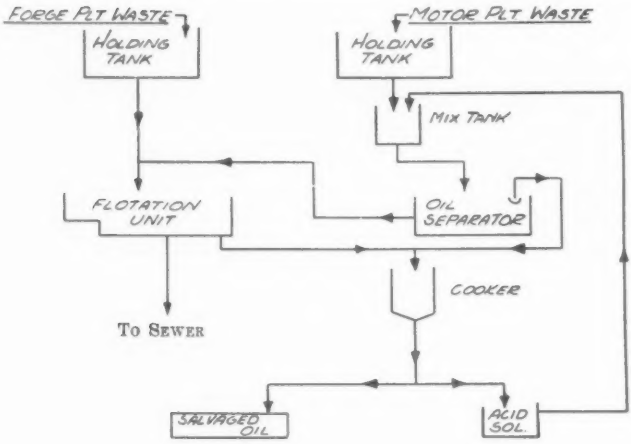
The first operation consists of dosing and rapid mixing the waste with a combination of aluminum sulfate and sulfuric acid. This reduces the pH from about 10 to about 4, with the coincidental precipitation of a small amount of floc. Mixing is accomplished in a circular tank with bottom influent and top effluent. The retention time is about 20 min.

Gravity separation of floating oil and floc is accomplished by passage through a rectangular tank with a surface baffle at the effluent end and a skimming trough. The retention time in this tank is 4 hr.

The partially clarified water is then ready for final treatment, which consists of flocculation, and flotation with the aid of dissolved air. The equipment used is one of the currently marketed flotation units equipped with a pump, air injector, modulating valves, pressure tank, and flotation chamber.

The partially clarified water passes from the gravity separator to a 1,000-gal. surge tank, from which it is drawn by the flotation unit pump. Air and caustic are injected at the pump. The liquid, now with a pH of 6.5, is pumped into a pressure tank, where the air is dissolved by the water. The drop in pressure which results when the water passes to the flotation unit

* Presented at 1954 Spring Meeting, New York Sewage and Industrial Wastes Assn.; Syracuse, N. Y.; June 14–15, 1954.



FLOW DIAGRAM - CHEVROLET TONAWANDA

FIGURE 1.—Simplified flow diagram of forge and engine plant wastes treatment system.

causes the air to emerge from solution. The minute bubbles adhere to the floc and oil particles, and by their buoyancy raise these particles to the surface. A series of mechanically-operated flights skim the floated material to a scum holding compartment. The clarified water is drawn from the bottom of the unit through perforated pipes and adjustable risers to the top of a small holding compartment, from which it passes to the sewer.

The material skimmed from the gravity separator after the acid-alum treatment is combined with the scum from the flotation unit and transferred to a 1,000-gal. cooking tank. Here it is treated with sulfuric acid and heated close to the boiling point. The acid reacts with the aluminum hydroxide floc, producing a solution of aluminum sulfate. The oil adsorbed on the floc is liberated and rises to the surface. The solution of aluminum sulfate and unreacted sulfuric acid is transferred then to a large sump, where it is held until needed as a dosing chemical in the initial step of the process.

The foregoing process has been described with extreme brevity because the treatment system for the engine and forge plants described in the following section, embraces a similar process in much greater size and detail.

Engine and Forge Plants

The oily wastes from the automobile engine plant are quite similar to, but much larger in volume than, those from the aviation engine plant. The method of collecting these wastes and the estimation of the volumes involved were based largely on experience gained in handling a similar problem at another location. The plant under discussion is expected to yield a maximum flow of oily water of about 15,000 g.p.h. It is quite possible that this may average about 6,000 p.p.m. of oil.

The waste from the forge plant is expected to originate largely around the forging machines. This is expected to be rather large in volume, about 42,000 g.p.h. maximum. The oil content may be about 200 p.p.m.

The high oil content and comparatively low flow rate of the engine plant waste seems to indicate the advisability

of segregating this material and applying a preliminary treatment before mixing with the larger flow from the forge plant.

Figure 1 is a simplified flow sheet showing the main components of the system. Figure 2 shows the elevations and water levels of the various pieces of equipment discussed.

All process waste water containing oil from the engine plant is to be routed to a 200,000-gal. holding tank. This tank serves a double purpose—it acts as a surge tank to even out the flow to the treatment system and also tends to even out the variations in composition. The cylindrical tank is divided diametrically into two compartments so that one section can be cleaned while the other is in operation. A horizontal skimming trough is provided on each side of the partition so the floating oil can be removed for special treatment whenever such a procedure is necessary or advisable.

The waste is pumped from the holding tank to a 3,000-gal. mixing tank, where it is treated with a combination of aluminum sulfate and sulfuric acid. The emulsion is almost completely broken and some floc is formed. From the mixing tank the waste flows by gravity to a 50-ft. long oil separator with a 2-hr. retention time. The combination of oil and floc rises to the surface for mechanical skimming. It then flows to a storage tank to await further treatment. The effluent water, still containing some oil, flows to a 15,000-gal. holding tank, where it mixes with the waste from the forge plant.

Waste from the forge plant is collected in sumps throughout the plant. then is pumped to two 50,000-gal. concrete holding tanks adjacent to the plant. It is then pumped through a long overhead line to the treatment plant, which is located near the engine plant.

Mixed wastes from the two plants containing some aluminum sulfate in solution, are pumped to the flotation units. Of the two units provided, each has a rated capacity of 700 g.p.m., although they are to be used at a rate of only 500 g.p.m. An automatic control system provides for recirculation of the effluent from the flotation unit back to the 15,000-gal. holding tank whenever the flow of waste into the holding tank becomes less than the pumping rate to the flotation system.

A general description of the operation of the flotation equipment has been given in the previous discussion of the aviation plant set-up.

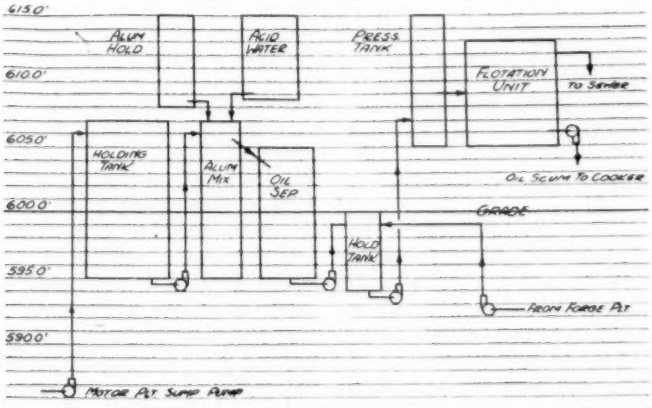


FIGURE 2.—Relative elevations and water levels of forge and engine plant wastes treatment system components.

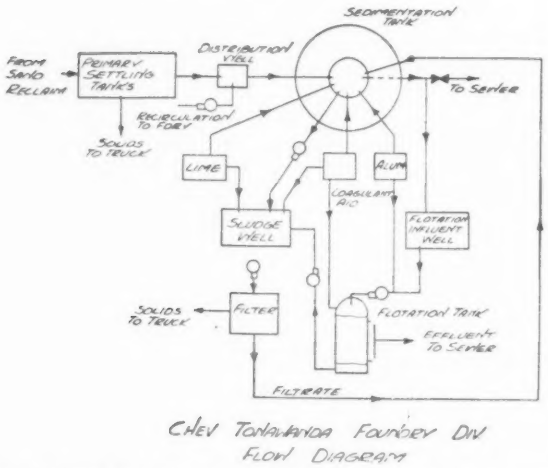


FIGURE 3.—Simplified flow diagram of foundry wastes treatment system.

The floated scum from the first treatment of the engine plant waste, and scum from the flotation unit, are pumped to a steam-heated, conical-bottom cooker, where the action of heat and sulfuric acid separate most of the remaining water from the oil. The acid and alum solution is drawn off the bottom to be re-used in the first mixing operation. The oil layer, which may still contain about 10 per cent water, is combined with similar oil from previously treated batches and subjected to a boiling treatment. This drives off most of the remaining water. The oil is then pumped to a salvaged oil storage tank.

Four cookers have been provided. They are steam-heated, conical-bottom, lead-lined tanks of 2,000-gal. capacity each.

A building of masonry construction houses the treating equipment, which is located on three separate levels. The upper level contains the alum and caustic holding tanks and a large holding tank for the sulfuric acid and reclaimed alum combination. This location permits these chemicals to be delivered by gravity to the points of treatment. A grating walkway permits easy access to all of these units.

The main floor level, about 4 ft. above grade, is the location of the flotation units and their pressure tanks, and also functions as the operating level of the large mixing unit, the gravity oil separator, and the cookers.

The lower level is the location of the lower portions of the large units, such as the oil separator and cookers, and the 15,000-gal. surge tank plus various pumps and other incidental equipment.

A large sump below the lower floor collects all of the treatment plant drainage. This liquid is automatically pumped back into the treatment system.

Foundry

The problems faced by Chevrolet relative to the disposal of foundry wastes are those concerned mostly with floating and settleable solids. The molding sand used at this plant is to be reclaimed for re-use by special washing and conditioning equipment, discharging as a residue all the constituents of the molding mixture except the re-usable sand. The contaminants include fine sand, sea coal, graphite, oxides of metal, and clay.

The waste water is expected to contain from 3,000 to 6,000 p.p.m. of sus-

pended solids, which will consist of the materials mentioned, plus smaller amounts of material from dust arresting and miscellaneous equipment. The total flow of this waste will be about 1,800 g.p.m. Figure 3 is a simplified flow diagram of the foundry wastes treatment system.

The wastes are first collected in one of two concrete settling tanks each 100 ft. long, 20 ft. wide, and 15 ft. deep. The retention time is about 1 hr. The waste water enters one end of the tank through a transverse distribution trough and leaves by overflowing adjustable notched weirs located on the other three sides of the tank. The conditions prevailing in this tank should allow the relatively large particles of sand and other debris to settle, leaving a water containing extremely fine suspended solids.

One tank is used until there is a sufficient accumulation of solids to impair the efficiency of the sedimentation process. The flow is then directed through the other tank while the first is dewatered for removal of the solids by a clamshell bucket on an overhead crane.

About 1,500 g.p.m. of the effluent from the primary settling tanks is recirculated to the foundry; the balance is further treated before it is discharged to a sewer, where it joins treated wastes from the adjoining motor and forge plants and flows to the Niagara River.

The water requiring further treatment was estimated, by difference, to amount to about 300 g.p.m. For design purposes this figure was expanded to 600 g.p.m., or about 200 per cent of the estimated flow. Because of the nature of this particular waste, the pipe conveying the water to the secondary clarifier is above ground to facilitate cleaning in event of a stoppage. The concrete clarifier is 55 ft. in diameter and has a 15-ft. side-water depth. Provisions have been made to equip the tank with mechanical sludge scraping and skimming mechanisms. Besides having a sludge sump at the apex of the conical bottom, the tank is equipped with a down-flow center coagulation zone containing a motor-driven paddle flocculator. Provisions have been made for adding coagulating chemicals in this zone. At the design flow of 600 g.p.m., the flocculation period is about 30 min. The treated waste enters the sedimentation zone through the bottom of the coagulating chamber. The detention period in the sedimentation chamber is about 6½ hr. Mechanical sludge removal is provided. The clarified water overflowing a peripheral weir may be discharged to the sewer system or routed to a holding or surge basin prior to additional treatment.

It has been reported and some experimental work prior to design has indicated this particular type of waste to be more amenable to separation by floating the solids with the aid of dissolved air. For this reason, the equipment includes a flotation cell, which can be used for additional clarification if necessary. The waste water can be taken as a partially clarified effluent from the overflow weir of the sedimentation tank, or all the waste water may be drawn off the bottom of this tank, and routed to the influent well prior to being pumped to the flotation equipment.

In the event that the suspended matter settles satisfactorily in the sedimentation tank, the sludge will flow by gravity, or will be pumped, depending on the concentration of solids, to a sludge basin. The sludge basin is sized to contain about 16,800 gal. normally, with an emergency capacity of 21,000 gal. According to estimates, the normal capacity will hold about 8 hr. accumulation of sludge. In the sludge basin, chemical additions may be made to improve the filtering or dewatering characteristics of the solids. A double-turbine-type slow-turning mixer in the basin insures uniform

consistency of the sludge. Also, if floated solids are introduced the mixer provides a means of de-aerating and defoaming the scum from the flotation tank.

In the event that clarification is not satisfactorily completed in the sedimentation tank, the effluent is routed to the influent well prior to flotation. Feed pumps used to charge the flotation unit are sized to permit variable quantities to be pumped to the flotation machine, depending on the rate of flow into the influent well.

The sludge after either the flotation or the sedimentation treatment is expected to contain about 10 per cent solids. This concentration of solids does not permit easy disposal. Additional dewatering of the sludge is accomplished on a rotary drum vacuum filter. The residue, containing approximately 50 per cent moisture content, is discharged onto a screw conveyor, where addition of hot fly ash tends to evaporate more water and increase the solids content. The screw conveyor is situated so that it extends over a truck driveway so the waste material can be hauled to a dumping area. The filtrate can be recirculated to the sedimentation tank, or if it is sufficiently devoid of suspended matter it may be routed to the sewer system. Relative elevations of tanks and equipment are shown in Figure 4.

The waste treatment building, of masonry construction, immediately adjoins the sedimentation tank, thereby reducing sludge piping to a minimum. The building consists of three levels, the lower level containing the flotation influent well, the sludge basin, and the lime slurry receiving basin, all built as a part of the building itself. Also contained in the lower level are the foundry recirculating pumps, the sedimentation tank sludge pumps, the flotation feed pumps, and the lime slurry pumps. The second level, or ground floor, contains the flotation system, the lime receiving area, the chemical storage area, equipment for mixing chemicals, and an area set aside for chemical

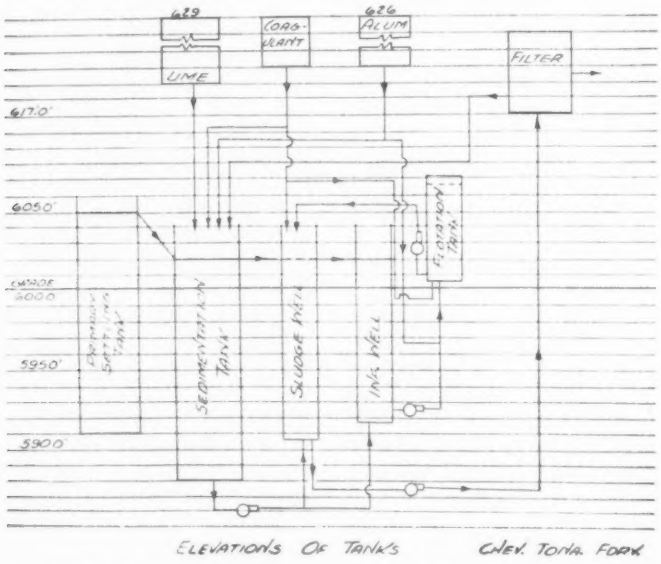


FIGURE 4.—Relative elevations and water levels of foundry wastes treatment system components.

laboratory control use. The third level houses the dewatering filters, the chemical holding tanks, a 10,000-gal. lime storage tank, and a fly ash storage bunker, as well as equipment for distributing fly ash and conveying dewatered sludge out of the building to waiting trucks.

Special Construction Details

All tanks subjected to contact with materials of low pH are lined with neoprene or lead. In the system for the motor and forge group the alum-sulfuric acid mixing tanks, the oil separator, and the oil mixture storage tanks are lined with ⅛-in. thick neoprene. The acid-water tanks, cookers, and evaporators are lead-lined. All piping used to convey corrosive liquids is plastic-lined. The pumps for these liquids are made from stainless-type materials impervious to attack. The concentrated sulfuric acid tank is steel and the conveying piping is wrought iron. Dilute sulfuric acid piping is plastic-lined. Protection against less corrosive substances is attained by the use of acid-resistant paints.

The pumps and mechanical equipment for the foundry waste treatment required special consideration with regard to abrasion resistance.

Special care was exercised in designing adequate cleanout ports in all piping. Some locations are provided with fittings so that both compressed air and water can be used to open plugged lines and flush the piping.

Protection against difficulties encountered due to stoppages has been provided by necessary overflow and by-pass arrangements.

Provisions also have been made and space allotted for future expansion of all waste treatment facilities should such be necessary.

FLORIDA PLANT APPROVALS IN FIRST HALF OF 1954

During the first six months of 1954, plans were approved by the Sewage and Industrial Waste Section of the Bureau of Sanitary Engineering, Florida State Board of Health, for 20 new sewage treatment plants costing an estimated $1,661,500 and designed to serve 55,500 people. Plans also were approved for additions to existing treatment plants and sewer systems and installation of new sewer systems to serve 148,000 people, costing an estimated $5,578,600. Thus, to total estimated cost of approved projects in the municipal category was $7,240,100 for the 6-month period as compared with $6,102,700 for the entire previous year.

In addition, a total of 65 municipal sewerage projects was approved during the first six months of 1954, as compared with 47 for the entire year 1953.

Miscellaneous projects approved included individual waste treatment facilities for 7 laundries, 1 restaurant, 6 schools, 8 tourist and trailer courts, a produce terminal, a recreation park, a shopping center, and a manufacturing plant. The cost of these projects was estimated at $188,200.

Increased interest was shown on the part of industry during the same period with regard to treatment of waste. As an example, a pilot plant was constructed to study citrus waste treatment.

TREATMENT OF SULFUR MINE WASTE WATER*

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The purpose of this paper is to present an account of the way in which a threatened air and water pollution problem incident upon the development of a modern sulfur mining operation in an urban area was forestalled through devising and placing in successful commercial operation a new and novel process for the treatment of sulfur mine waste water. This brief account is intended to include a historical and theoretical background of the new process, together with a description as to flow pattern, equipment, and operating data of the commercial plant now in operation near Beaumont, Tex., at the Spindletop Dome mine of the Texas Gulf Sulphur Company.

In mining sulfur by the Frasch process, large amounts of waste water accrue. Because the volume of the hot fresh water entering the formation to melt the sulfur far exceeds the volume of melted sulfur removed, great underground pressures would build up were it not the general practice to bleed water from the bottom of the formation at the flanks of the dome. Since the cold brine, or formation water, originally present in the sulfur-bearing stratum is heavier, it seeks these lower levels, while the warm fresh water tends to rise in the formation to melt sulfur, or at least to warm it. Thus, the first waste water in a sulfur mining operation is formation water.

* Presented at 1954 Southern Industrial Wastes Conference; Houston, Tex.; Apr. 21–23, 1954.

Composition of Waste Water

As mining continues, the formation water slowly becomes diluted with the fresh water, and with this dilution there is generally some rise in temperature. It might at first be thought possible to reheat this waste water and to return it to the formation for melting more sulfur. When this has been attempted in the past, however, difficulties have soon arisen both with scale formation and with excessive corrosion, as softening the water before reheating is out of the question because of the quantities of chemicals involved.

To illustrate, Table I gives a typical analysis of waste water from Spindletop Dome; this is the water with which the treating process is required to deal. It will be noticed that it contains, in addition to 74,000 p.p.m. sodium chloride, substantial quantities of other chlorides, sulfates, bicarbonates, and sulfides of sodium, calcium, and magnesium. As far as has been determined, sulfides are present in this water at its wellhead pH of approximately 6.5 as dissolved hydrogen sulfide and as polysulfides, the water having a yellow color which is eliminated upon removal of the sulfides.

Waste Water Liberates Gases

Were the raw waste water discharged to a receiving stream through open ditches in an urban area, significant problems of air and/or water pollution would result. Although

TABLE I.—Analysis of Raw Waste Water[1] (Sulfur Mine Waste Water), Spindletop Dome

Constituent	p.p.m.
(a) Base Analysis	
Soluble sulfide	270
Calcium	2,400
Magnesium	560
Sodium	29,200
Bicarbonate	430
Sulfate	2,240
Chloride	49,000
(b) Hypothetical Combinations	
Calcium bicarbonate	570
Calcium sulfate	3,200
Magnesium chloride	2,190
Calcium chloride	3,660
Sodium chloride	74,200

[1] pH 6.5.

much experience has shown that natural aeration in open ditches does not produce toxic or even dangerous concentrations of hydrogen sulfide in the surrounding atmosphere, nuisances of odor and of paint blackening ensue. Further, should the raw waste water be absorbed into a receiving stream without prior removal or evolution of sulfides, its high chemical oxygen consumption, corresponding in the case of the waste water analysis shown to an iodine demand of 270 p.p.m. as sulfide, would exert a deleterious effect on stream condition, the magnitude of which would depend on prior stream history and the relative volumes of stream and waste water.

Sulfides Must Be Oxidized

This is obviously not a situation for the use of gaseous chlorine to oxidize the sulfides to benign salts, as is practiced in the case of natural household waters having low sulfide concentrations (1), for the costs would be prohibitive. It might at first be thought that a purification from sulfides could be effected with the recovery of an equivalent amount of sulfur, but this has not yet been accomplished because of the large volume of water involved. The treatment and disposal of this waste water to eliminate or to minimize the odor nuisance and to avoid intolerable stream pollution is a recognized problem in the American sulfur industry, for the amount of waste water displaced from the mine is usually about equal to the volume of fresh water used for mining, amounting to several million gallons per day even at a small mine.

Fortunately for sulfur producers, most of the deposits so far worked have been located on the shores of the Gulf of Mexico, usually in sparsely settled districts. In these cases, the waste water has been ditched directly to the Gulf or to connecting bays. At other mines, the waste water has been impounded and/or aerated by spraying for a time sufficient to allow the escape of the sulfides as gaseous hydrogen sulfide and then wasted to brackish streams. Again, when salty or brackish streams were not close to the mine, the sulfide-free water from the impounding basins has been released to fresh water at low rates or during periods of high stream flow so as not to effect aquatic life adversely.

Sulfide Removal

In locations where none of the foregoing techniques were utilizable, due either to extreme distance from tidewater or to too great a population density, the waste water has been treated for disposal by various processes having as common features the gas scrubbing of the raw bleedwater and the dispersion of the sulfide-bearing scrubbing gas from tall stacks to minimize atmospheric pollution at ground level. In this treatment method, the waste water is scrubbed with flue gas, the carbon dioxide of which maintains the pH value of the bleedwater substantially constant at about pH 7 to permit chemical release of the sulfide. Under these conditions, noticeable concentrations of

hydrogen sulfide are not found at ground level except during infrequent unfavorable atmospheric conditions, yet the method is not considered suitable for use where the sulfur mines are located in urban areas. This treatment method is well known to the industry (2)(3).

Need for New System

It was the general feeling of the company officials responsible for the development of the Spindletop Dome mine of the Texas Gulf Sulphur Company that none of the conventional sulfur mine waste-water treatment methods would be satisfactory, for inherent in all of them was the possibility that hydrogen sulfide, either from open ditches or from the treatment process, might reach ground level and produce undesirable levels of pollution. What was required here was the development of an entirely new process of sulfur mine waste-water treatment from which there would be no emission of hydrogen sulfide and whose product would be stable water, which could be received without ill effect into the adjacent Neches estuary.

In this situation, recourse was had to a corrolary of the traditional Wackenroder reaction, in which gaseous hydrogen sulfide is passed into a dilute solution of sulfurous acid with production of a milky, opalescent suspension of colloidal sulfur and solution of various sulfur acids. The present process consists of contacting the raw waste water with a commensurate quantity of dilute sulfurous acid with provision for adequate mixing and subsequent adequate reaction time at pH levels from pH 2 to pH 4. This process converts soluble sulfide to insoluble elemental sulfur and to soluble and insoluble salts, such as thionates, polythionates, thiosulfates and sulfates. The insoluble sulfur and the insoluble salts can easily be removed by conventional clarification processes without odor nuisance, and the soluble salts have given rise to no serious problems of stream pollution.

Chemistry is Complex

The exact reactions between the sulfurous acid solution and the hydrogen sulfide-containing waste water are not fully known, but the net result is a quantitative yield of colloidal insoluble sulfur and various soluble and insoluble sulfur compounds, mainly sulfites, thiosulfates, sulfates, thionates, and polythionates. The probable reactions are as follows:

1. *Solution of Sulfur Dioxide in Water*

$$\underset{\text{(Sulfur dioxide)}}{SO_2} + H_2O \rightleftharpoons \underset{\text{(Sulfurous acid)}}{H_2SO_3} \qquad (1)$$

$$H_2SO_3 + SO_2 \rightleftharpoons \underset{\text{(Pyrosulfurous acid)}}{H_2S_2O_5} \qquad (2)$$

or

$$2SO_2 + H_2O \rightleftharpoons \underset{\text{(Pyrosulfurous acid)}}{H_2S_2O_5} \qquad (3)$$

2. *Primary Reactions*

$$H_2S_2O_5 + H_2S \rightleftharpoons \underset{\text{(Sulfoxylic acid)}}{H_2SO_2} + \underset{\text{(Disulfoxylic acid)}}{H_2S_2O_3} \qquad (4)$$

$$H_2S_2O_3 + H_2O \rightleftharpoons \underset{\text{(Sulfoxylic acid)}}{2H_2SO_2} \qquad (5)$$

$$H_2SO_2 + H_2S \rightleftharpoons \underset{\text{(Sulfur)}}{2S} + 2H_2O \qquad (6)$$

$$S + H_2SO_3 \rightleftharpoons \underset{\text{(Thiosulfuric acid)}}{H_2S_2O_3} \qquad (7)$$

$$2H_2S_2O_3 \rightleftharpoons \underset{\text{(Hydrogen sulfide)}}{H_2S} + \underset{\text{(Trithionic acid)}}{H_2S_3O_6} \quad (8)$$

3. *Secondary Polythionate Reactions*

$$H_2S_3O_6 + H_2S_2O_3 \rightleftharpoons \underset{\text{(Tetrathionic acid)}}{H_2S_4O_6} + H_2SO_3 \quad (9)$$

or

$$3H_2S_2O_3 \rightleftharpoons H_2S + H_2SO_3 + H_2S_4O_6 \quad (10)$$

or

$$H_2S_2O_6 + S \rightleftharpoons H_2S_4O_6 \quad (11)$$

and

$$H_2S_4O_6 + S \rightleftharpoons \underset{\text{(Pentathionic Acid)}}{H_2S_5O_6} \quad (12)$$

or

$$H_2S_4O_6 + H_2S_2O_3 \rightleftharpoons H_2S_5O_6 + H_2SO_3 \quad (13)$$

Alternatively, the primary reactions may be considered to involve the hypothetical sulfur acid $H_2S_2O_2$, as follows:

2—A. *Primary Reactions*

$$H_2S + SO_2 \rightleftharpoons H_2S_2O_2 \quad (14)$$

$$H_2S_2O_2 + H_2S \rightleftharpoons 3S + 2H_2O \quad (15)$$

$$H_2S_2O_2 + 2H_2SO_3 \rightleftharpoons H_2S_4O_6 + 2H_2O \quad (16)$$

The corresponding alternate secondary polythionate reactions are as follows:

3–A. *Secondary Polythionate Reactions*

$$H_2S_4O_6 + H_2SO_3 \rightleftharpoons H_2S_3O_6 + H_2S_2O_3 \quad (17)$$

$$S + H_2SO_3 \rightleftharpoons H_2S_2O_3 \quad (18)$$

$$H_2S_4O_6 + H_2S \rightleftharpoons S + 2H_2S_2O_3 \quad (19)$$

$$H_2S_2O_2 + 2H_2S_2O_3 \rightleftharpoons H_2S_6O_6 + 2H_2O \quad (20)$$

$$H_2S_6O_6 \rightleftharpoons H_2S_5O_6 + S \quad (21)$$

The foregoing reactions are written as proceeding from the reactants on the left to the products on the right, although in all reactions the participants are subject to equilibrium, even the insoluble colloidal sulfur participating by virtue of its nascent condition rather than immediately separating out by precipitation.

The progress and equilibrium state of each of the reactions are affected by the pH of the medium. At pH 2 to 4 it is believed that the predominant reactions are those of Eqs. 1 through 7 or, alternatively, Eqs. 14 through 19, producing predominantly sulfur, sulfite and thiosulfate.

Commercial Process

This new sulfurous acid process for the treatment of sulfur mine waste water has been reduced to commercial practice at the Texas Gulf Sulphur Company's Spindletop Dome mine near Beaumont, Tex. Construction began in the late fall of 1951 and initial operation in the early summer of 1952. The process has been proven

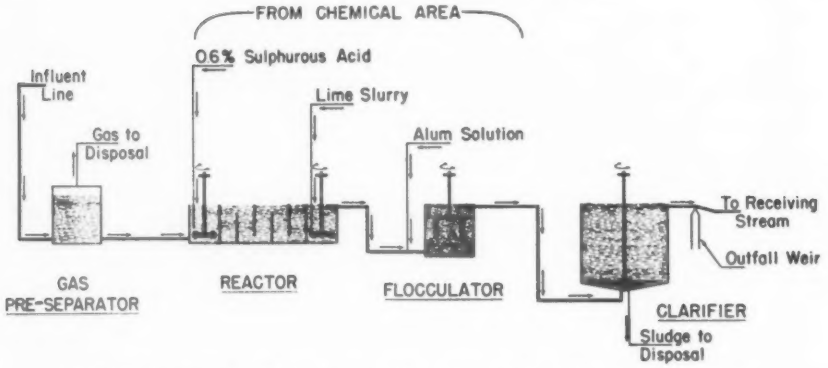

FIGURE 1.—Flow diagram for sulfur mine waste-water treatment plant.

by two years of successful application, large volumes of waste water having been treated without giving rise to either atmospheric or stream pollution.

A simplified flow diagram is given in Figure 1. The influent line is a 16-in. diameter, class 150, asbestos cement line, through which the sulfur mine waste water flows from the closed waste-water well discharges under pump pressure to the gas pre-separator, the latter being an 8-ft. square by 15-ft. high concrete vessel in which the large amounts of hydrocarbon gases contaminated with hydrogen sulfide are separated from the bleedwater and removed for disposal elsewhere.

Chemical Control Important

It should be noted that once received into the gas pre-separator, the sulfur mine waste water is under its own hydraulic head and the flow through the remainder of the process is entirely by

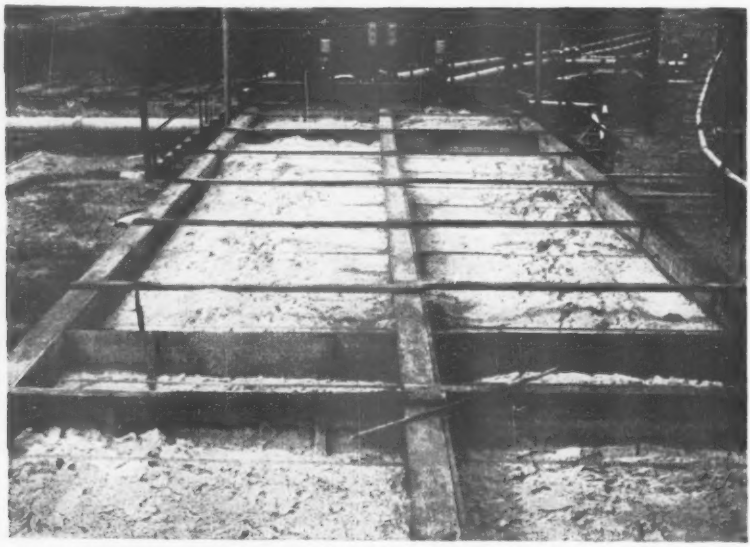

FIGURE 2.—Reactors, with gas pre-separator at upper right.

TABLE II.—Summary of Equipment and Retention Periods

Unit	Size	Material of Construction	Auxiliary Equipment	Retention Time (min.)[1]
Influent line	Dia., 16 in.; length 1,600 ft.	Asbestos cement	—	—
Gas pre-separator	8 ft. by 8 ft. by 15 ft. deep; 6-ft. liquid depth	Concrete	—	4.3
Reactor	Two parallel units, each 10 ft. by 110 ft. by 6 ft. deep; 4.7-ft. liquid depth	Redwood	Externally-mounted turbine mixers in acid and lime mix cells	111.1
Flocculator	Two parallel units, each 18 ft. by 18 ft. by 12 ft. deep; 11-ft. liquid depth	Concrete	Downdraft mixer units	77
Clarifier	Two parallel units, each 50-ft. dia. by 14.5-ft. depth, cone bottom	Concrete	Sludge rake and oil skimmer	631
Outfall weir	4-ft. wide, broadcrested	Creosoted timber	—	—

[1] Minutes for normal flow at 1 m.g.d.

gravity. From the gas pre-separator the waste water flows to the reactor (Figure 2), entering first the parallel acid mixing cells at the influent end of the reactor, where it is flash mixed with a commensurate quantity of 0.6 per cent sulfurous acid by weight, produced by the burning of sulfur and absorption of the burner gas in conventional equipment. The acid mixing

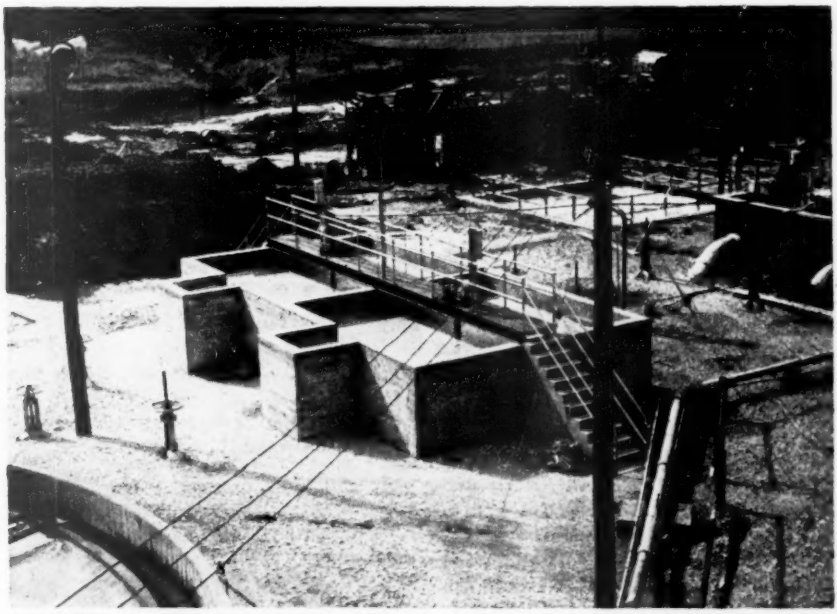

FIGURE 3.—General view of sulfur mine waste-water treatment plant, showing: chemical storage tanks, background; reactors, right; flocculators, center; and clarifiers, lower left.

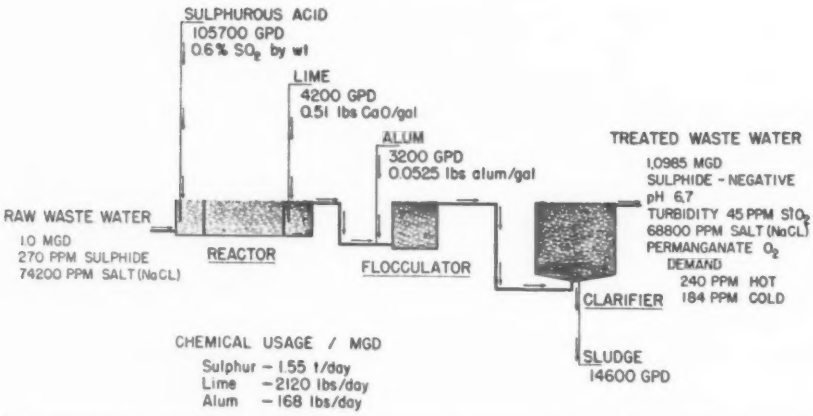

FIGURE 4.—Volume balance and operating summary of sulfur mine waste-water treatment plant at normal flow of 1 m.g.d.

cells at the influent end of the reactor are covered and sealed against gas evolution from the process, this being the only point at which H_2S tends to be evolved. As noted in the equipment summary (Table II), the reactor is an open redwood tank of rectangular shape containing at each end two 10-ft.-square parallel mixing cells on the intake for sulfurous acid and on the outlet for lime, together with two parallel 90 ft. long by 10 ft. wide detention tanks in the center baffled against short circuiting. The pH of the waste water is maintained at 2.8 for the requisite detention time and is then increased to approximately 7.2 by the addition of a 0.5-lb.-per-gallon lime slurry in the lime mixing cells at the effluent end of the reactor tank.

From the reactor the waste water flows to flocculators (Figure 3), each 18 ft. square by approximately 11 ft. liquid depth, where the 0.0525-lb.-per-gallon alum solution added in the line between the reactor and the flocculator is agitated slowly to produce a precipitate of desirable settling characteristics. From the flocculators the water flows at pH 7.2 by gravity to the two parallel 50-ft. diameter by 14.5-ft. liquid depth clarifiers, with equipment for oil skimming and sludge removal. From the effluent weir of the clarifiers the treated water is discharged through an outfall weir to the receiving ditch, which carries it approximately 2,900 yd. to oil skimming and surface waste-water disposal facilities for the entire Spindletop Dome area.

It will be noted from Table II that the total retention time for the process at 1 m.g.d. throughout is about 13.7 hr.

An operating summary for the plant is presented in Figure 4, which depicts plant performance at its normal capacity basis of 1-m.g.d. input of raw sulfur mine waste water. It will be noted that the original sulfide has been completely destroyed and that the effluent is a comparatively stable, neutral, clear salt water.

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CONSTRUCTION AND MAINTENANCE OF INDUSTRIAL SEWERS *

By Ernest K. Smith

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Through the years sewers have come to be classified as either storm-water, sanitary, or combination sewers. However, the development of modern industry with its increased use of water in its processes for washing, heating, and cooling has forced the need for another classification of sewers known now as industrial sewers.

Engineers are thus confronted with the problem of finding suitable materials and construction methods to produce a sewer that can withstand the chemical action of the acids and alkaline wastes that must be discharged, as well as receive the shock of extreme temperature changes necessarily received from various manufacturing processes. In addition, means are continually being devised to facilitate inspection, repair, and cleaning of these relatively new industrial sewers.

This paper endeavors to present something of the knowledge and experience gained by the Engineering and Maintenance Division at the Kodak Park works of the Eastman Kodak Company in Rochester, N. Y., through years of constructing and maintaining industrial sewers for the industry that produces photographic film and chemicals, as well as other chemical compounds sold as such.

The Kodak Park plant occupies 579 acres and employs approximately 20,000 people. The industrial sewers vary in size from 8 to 64 in. in diameter and total approximately 14 mi. in length. These sewers carry to a disposal point the discharge from such industries within an industry as a paper mill, a gelatin manufacturing plant, a plant manufacturing sulfuric acid, silver recovery from waste film and liquids, manufacture of artificial leather, processing of color pictures, production of vitamin tablets and compounds, a plant for the recovery of solvents, manufacture of photographic chemicals, and the wastes resulting from the production of 28,000 tons of refrigeration and 30,000,000 lb. of steam daily.

From this outline of the wastes received it can be readily seen that waste temperatures are sometimes high. Lime, cinders, acids, and various salts are received into the sewer, and the pH of the wastes on occasion runs off the normal scales in either direction. Waste temperature in the sewers is generally at 120° F., since the extremes modify each other and with a flow of approximately 18.5 m.g.d. temperature rises are slow, except in the smaller sewers and laterals.

Types and Sizes

These sewers have been constructed of a variety of materials depending upon the judgment of the engineer in charge at the time of construction, the size of sewer required, and to some extent on the materials available at the time of construction. For example, about 0.4 mi. of 48-in. diameter brick sewer constructed about 1909 has cement mortar joints. Another 0.8 mi. of 48-in. diameter sewer constructed about 1918 is of vitrified tile segmental block with cement mortar joints. The more recently constructed 48-in. sewer

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(built in 1945 and 1952) is of concrete pipe having vitrified tile liner plates with hot-poured sulfur cement joints. In general, however, sewers of 36-in. or smaller diameter are built of vitrified clay pipe with various joint materials.

Construction

Sewer construction in areas being newly developed presents no particular problem that is unusual to sewer construction generally. Fortunately most of plant work is of this nature. When sewers must be replaced or constructed in crowded industrial areas where manufacturing processes are continuous and materials and products must be kept moving either by truck, or railroad, or both, serious problems arise in construction schedules and methods. Then there are, of course, all the other underground facilities, such as drinking-water mains, fire mains, water mains for industrial use, electric ducts, steam lines, process piping, and tanks that have to be moved or supported and crawled under.

Construction costs are necessarily high in these areas because of the extra sheeting necessary to confine the work and support other facilities. It usually is necessary to haul away excavated materials, at least at the beginning of the work, and then haul back material when the sewer is completed. Work must be done in short lengths and after the work is started newly excavated material can be used for backfill on the last completed length of sewer. Where rock excavation is required it is often necessary to break out the rock with a point when blasting would cause prohibitive jar to processes in the area.

Present practice is to use vitrified clay pipe for most sewer work 36 in. or less in diameter, except where extreme conditions are anticipated. Where sewers larger than 36 in. in diameter are required concrete pipe with vitrified tile liner plates is used. Other material, such as plain concrete pipe, asbestos cement pipe, and iron pipe are not considered suitable because of the acid content of the waste.

The joint is made by first caulking with dry twisted jute or asbestos rope and pouring the joint with a hot-poured sulfur cement compound. These materials have been selected as suitable for use under most conditions found in this chemical industry. Dry jute or asbestos rope have been selected as caulking materials because oakum is oily and leaves an oil film on the vitrified tile, destroying the bond between the sulfur cement and the tile.

Asphaltic materials have been used, but it has been found that these materials tend to flow under the continued high temperatures and in time the joint material is found in the bottom of the sewer. The hot-poured sulfur cements set up quickly and make a rigid joint that is equally as strong as the vitrified tile pipe.

All sewers are constructed on standard concrete cradles, regardless of soil conditions. A good foundation on any structure is good economy. This is especially true for sewers, as the cost of the cradle is small compared with the total cost and the inconvenience of construction. The concrete cradle insures a rigid foundation to support a sewer that is made inflexible by the joint material used.

Exceptions to the foregoing are made to meet unusual conditions of location or extreme temperature. For example, when a sewer must be replaced or constructed in a busy section, every effort must be made to cause the least possible delay to truck and railroad movement of raw materials and finished products. On three occasions it was necessary to maintain traffic uninterrupted. This was accomplished by jacking tongue-and-groove concrete pipe between two points where jacking pits could be dug. On these occasions good line and grades were maintained by frequent checking; even

though jacking proceeded from both pits, the joint in the middle is so good that it is impossible to go through the sewer and find the joint where the two sections met. Jacking distances varied from 50 to 108 ft., depending on required distances and soil conditions.

Sewers constructed by jacking pipe are not usually sized to meet the flow requirements of the sewer. Instead the size is governed by the opening a man can effectively work in, probably a minimum of 30 in. in diameter.

Concrete pipe is considered a good sewer material and probably would serve for years under normal conditions; however, for this industrial use it is preferable to provide a protection for the concrete before the sewer is put into use. This is accomplished by the use of vitrified clay tile. Since the sewer is larger than it needs to be, it is usually necessary to install vitrified clay tile liner plates only in the bottom half of the sewer. The tile liner plates are placed in cement mortar, the joints are raked, and hot-poured sulfur cement is poured into the joints. Where the joints are vertical or nearly so, thin paper is pasted over the joint with sodium silicate to serve as a form. The top half of the concrete pipe is coated with a black asphalt paint. The first of these installations has been inspected after six years of use and found to be satisfactory in every respect.

One sewer lateral installation was required to receive a discharge of several hundred gallons of a 2 per cent solution of sulfuric acid, at a temperature of more than 200° F., at intervals of once a week. It was desirable that this discharge be completed in a few minutes so that a new cycle of the process could be begun immediately. It was feared that the usual clay tile sewer would be cracked by the repeated sudden rise from a normal ground temperature of perhaps 50° to the 200° temperature. Consequently, 10-in. diameter stainless steel tubing was encased in concrete to form this sewer. The type of stainless steel used was selected after first consulting the records of tests of various metals submerged in the sewers. These tests are being made continually with the cooperation of the company's metalurgical laboratory.

Manholes

Manholes used are the standard manholes of either brick or concrete pipe construction, with the exception that the bench walls and sides of the manholes to the top of the sewer are constructed of vitrified tiles or hard-burned bricks with hot-poured sulfur cement joints.

Maintenance

Maintenance includes inspection, cleaning, and repair.

Inspection

Inspection requires that an engineer or other responsible person enter the manholes, and sewers if possible, and actually see conditions as they are and take pictures.

Safety is important in any sewer, and in industrial sewers carrying chemical waste its effect on men must be guarded against. The inspector must use proper protective clothing, safe lights, and suitable gas masks. Finding a suitable mask presents a problem. Several types have been used. The usual canister type is not suitable if there is an oxygen deficiency. The mask receiving oxygen from a cylinder is good, except that if the oxygen bottle is carried on the back it is impossible for a normal man to get through a manhole opening or get around in the sewer. If the oxygen tanks are kept on the surface, the man in the hole is dependent on the small air line and its uncertain connections.

Finally, what appears to be a suitable mask has been selected. It is a combination of a source of compressed

air instead of oxygen in tanks on the surface and a small bottle strapped to the wearer's back for emergency use in case the air line becomes tangled or broken.

Automatic Vapor Alarm

A continuous check for an explosive atmosphere in the sewer is now maintained by using a clock recording device with an explosive meter. This instrument is so constructed that not only is a record made of the explosive intensity of the atmosphere in the sewer, but also when a danger point is approached an alarm bell rings in the fire station and the firemen proceed to turn fire hoses into the sewer for dilution. An alarm is also occasion for the engineers to investigate how an explosive substance got into the sewer and warn the department concerned of their loss.

Cleaning

Cleaning is a seasonal job for a crew of four men. Their equipment consists of flexible jointed sewer rods with an assortment of accessories and a trailer-mounted gasoline engine for turning the rods. The equipment is used first and is good for breaking through a sewer that is found completely stopped.

Since proper cleaning requires the removal of solid material from the sewer, a cable from a gasoline-powered winch or sewer machine is attached to the rods before they are pulled out of the sewer. Thus, the cable is drawn through the pipe for use with a small clamshell bucket. This bucket is then pulled in and out of the sewer by two trailer-mounted sewer machines. Solid materials removed are emptied directly from the clamshell bucket into a "load lugger" bucket for disposal.

Other equipment includes a rotary sewer cleaner for use primarily in buildings and for sewer laterals. This equipment can best be described as consisting of pieces of coiled steel spring, each approximately 15 ft. long, fastened end to end with a special joint. The long spring this formed can be thrust into a pipe and turned by a small machine powered by an electric motor. Special screws and cutters are provided with this equipment.

Some years ago flushing with fire hose and special nozzles was used almost exclusively. By this means flow was started again and the solids were moved along the sewer to cause a stoppage somewhere else.

Repair

Sewers constructed of materials used today have not required repair, serving this difficult industry with complete satisfaction for as long as nine years. Repair has been required mostly in the old 48-in. brick sewer. Apparently the fumes from the waste have not affected the cement mortar joints in the top half of the sewer, but the mortar in the bottom half of the sewer was completely gone. In the older section of the plant the industrial sewer also receives storm water; during periods of intense rainfall, the 48-in. sewer had been too small.

To repair the sewer would have required a means of diverting a flow of approximately 16 m.g.d. at that time. Consequently, it was found that the construction of a new sewer parallel to the old brick sewer would give the needed increased capacity and provide a way to divert the waste without pumping. This was the first use of the 48-in. concrete pipe with vitrified tile liner plates.

Completion of the new sewer was immediately followed by repair of the old brick sewer, whose invert had been constructed in from 2 to 4 ft. of rock excavation. A large portion of the invert was completely gone and required replacement with brick and concrete. Vitrified tile liner plates were then placed in the bottom half of the sewer in the same manner described previously for use with concrete pipe.

Other materials had previously been used for repair of this sewer. A large section had been coated with pneumatically applied cement mortar. This did not prove to be satisfactory and after relatively few years only traces of it could be found.

The first successful repair was made with redwood tongue-and-groove staves, such as are commonly used on wood tanks. This material could be installed without completely drying the sewer. The redwood invert installed in 1936 is in good shape and was not replaced with the tile liner plates.

Some repair has been made in the vitrified tile segmental block sewer. A few blocks in the sidewalls have been found broken. These broken blocks were chipped out and replaced with brick masonry backing and vitrified tile liner plates. On these occasions it was not always possible to pour the joints with the sulfur cement and an acid-proof mortar or paste was needed. An acid-proof resin cement known as "Alkor" was used. It is a good material, but has the disadvantage of requiring nearly 24 hr. to set up.

As can be readily seen, the greatest difficulty in sewer repair is to dewater the sewer for a period long enough to do the work. Because since only the large sewers can be inspected and worked in, repairs almost always necessitate pumping or otherwise diverting large volumes of water. This work is often done during periods of low flow by installing short sections of light-gage metal pipe of a smaller diameter in the large sewer and blocking it up off the invert. This can be done near manholes, but is difficult in long sections between manholes.

Conclusion

In conclusion it must be said that the construction and maintenance of industrial sewers is an interesting occupation. It is a never-ending search for and experiment with new materials and methods. As long as industry progresses to new products and produces ever-changing wastes the sewer requirement must change to meet new demands.

Acknowledgments

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CONTROL OF ACCIDENTAL DISCHARGE OF CYANIDE SOLUTIONS *

By B. A. Poole, R. H. Holtje, and W. G. Belter

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Expansion of Indiana's metalworking industry has produced a problem in industrial waste control that has required a unique solution. The crux of the problem is the prevention of accidental discharges of concentrated cyanide solutions into municipal sewers and streams.

Usual procedures within industrial plants had failed to check sporadic but continued killing of fish and livestock. The obvious hazard to humans which accompanied the killings could not be overlooked.

This situation was brought to a head in July 1952, when a plating solution containing 1½ tons of sodium cyanide was accidentally drained to the Lafayette, Ind., city sewer system and to the Wabash River. The solution was lost when the plant foreman failed to close a drain valve while filling the electrolyte tank. A 3-mi. long toxic slug started downstream, killing practically all aquatic life in its path. Natural dilution and chemical action gradually reduced and finally dissipated the toxicity in a 60-mi. stretch. Fortunately, the public water supply at the Terre Haute intake, located 30 mi. farther downstream, was not affected. This dramatic occurrence highlighted the necessity for positive preventive action by the Stream Pollution Control Board.

Consequently, a proposed regulation was drawn up and circulated for comment among officers of the Indiana Section, American Electroplaters Society. A draft also was sent to members of the Metal Finishing Industry Action Committee of the Ohio River Valley Water Sanitation Commission. Minor changes suggested by these nationally prominent platers, chemists, engineers, and executives were incorporated into the proposed regulation. After a public hearing, the Stream Pollution Control Board adopted the regulation, which became effective on January 10, 1953.

The Regulation

The regulation is brief. It states:

> Any person, firm or corporation engaged in manufacture or other process in which cyanides or cyanogen compounds are used shall have each and every room, where said compounds are used or stored, so constructed that none of said compounds can escape therefrom by means of building sewer, drain or otherwise directly or indirectly into any sewer system or watercourse;
>
> PROVIDED, however, that on application to and prior approval by the Stream Pollution Control Board, limited amounts, which it is determined would not be detrimental to public health or which would not pollute any lake, river, stream, drainage or roadside ditch or other water-course, shall not come under the provision of the paragraph above.

Removing the cautious legal terminology, the first paragraph says that wherever cyanide compounds are used or stored, there must be no access to a sewer system or stream. The second paragraph provides an exception

* Presented at 27th Annual Conference, Central States Sewage and Industrial Wastes Assn.; Richmond, Ind.; June 24–26, 1954.

wherever treatment of rinse water is unnecessary. It takes into account those plants where wastes containing small amounts of cyanide have not caused difficulty in the receiving stream or sewage treatment plant.

As a part of the stream pollution control law, which has an "about to pollute" clause, action can be taken before pollution occurs. The regulation is truly preventive.

Cyanide Questionnaire

As there was no list of cyanide users in the state, a questionnaire was mailed to 920 metalworking industries. A 91 per cent return has shown that actual users of cyanide are confined to 235 plants. Uses involved are plating, heat treating, pickling, metal stripping, and laboratory analyses. The first two constitute 90 per cent of the users.

As expected, the vast majority of users are located in urban areas. Half are connected to municipal sewer systems where treatment is provided. The majority of the remaining half of the users discharge either into sewer systems having no sewage treatment, or directly into streams.

The pin-pointing of these potential trouble spots has been beneficial to all concerned. State, industrial, and municipal sewage treatment personnel, making inspection of industries together, have come to recognize the need for and importance of closer cooperation between industry and municipality regarding common waste disposal.

Causes of Cyanide Spills

If cyanide spills are to be prevented, their cause should be thoroughly understood. Design of preventive works must allow for human error and mechanical failure.

Tank overflow (not tank failure) is the principal cause of cyanide spills. This fact cannot be overstated. Overflows have occurred when cooling coils, immersed in solutions, ruptured. Many overflows were the result of carelessness or negligence when water make-up accidents occurred. These situations are particularly dangerous when the accident happens after regular working hours.

Other spills have been caused by leakage or outright failure of a valve. Obviously, it is impossible to leave a valve open inadvertently if all drain valves on cyanide tanks are eliminated. Serious spills also have been connected with filtering accidents when hoses slipped their moorings or when hose clamps failed.

Experience in the investigation of a score of cyanide spills points up the fact that the "man-with-the-mop," the "valve turners," and the "low man on the totem pole" are key men in the prevention of cyanide spills. Without their educated cooperation and care, preventive devices can be all but nullified.

Preventive Methods

Considerable ingenuity has been displayed by designers of preventive works in plans submitted for review. Essentially, there are five methods of preventing spills, as follows:

1. Curbing.
2. Holding or storage tanks.
3. Pits or recessed floor areas.
4. Double-capacity tanks.
5. Miscellaneous.

Curbing

The most common method of isolating cyanide tanks from a sewer system or stream is a simple curb surrounding cyanide solution tanks. The volume of the curbed-in area around single cyanide tanks should be equal to or greater than the volume of the cyanide solution. Multiple tanks need not have 100 per cent volume protection. Curbs should be waterproof. Rinse waters are piped outside the curbed area to drains (Figure 1).

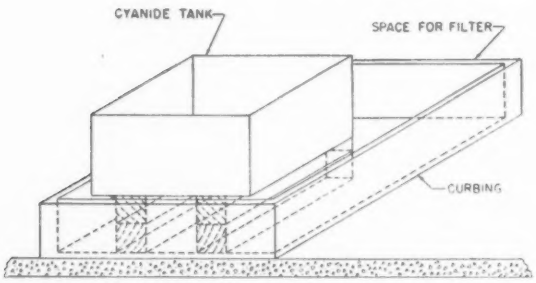

FIGURE 1.—Curbing to enclose cyanide plating area.

This method is useful in most job plating shops because of its simplicity of construction. More than one-third of the plans submitted employ this method.

There are many variations. In some situations, the entire plating area is curbed, floor drains are sealed with concrete or removed, and the rinse waters are piped outside the curb. Several plans have been submitted providing for a pan, under an out-of-the-way cyanide tank, which drains to a main curbed-in area.

Accumulations of dirt, solution drag-out, etc., within the curb may present a maintenance problem; but with ordinary good housekeeping, no real difficulties are anticipated. Hosing-down within the curb presents a hazard if

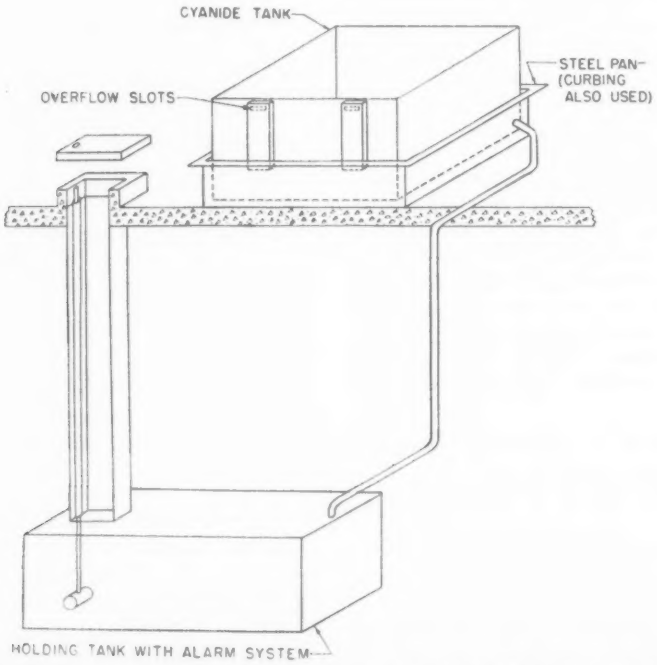

FIGURE 2.—Holding tank for retaining an accidental discharge of cyanide.

the contaminated water is siphoned or pumped into the sewer without checking to insure a low and safe cyanide content. Practically all plating establishments have cyanide titration equipment, chemicals, and at least one person to interpret the results and make the proper disposal decision.

Holding or Storage Tanks

The holding tank method involves the collection of spilled solution via overflow or floor drain and conveyance to a dry tank having sufficient capacity to retain the spill. The tank may be buried or in a basement or lower floor (Figure 2). Naturally, rinse waters are piped out of the area.

The method is particularly adaptable for use with automatic plating units. These units are generally surrounded by floor trenches which drain to the plant sewer system. By means of dams or pans, the cyanide portion of the units can be isolated and any spills diverted directly into a holding tank.

Where there are several cyanide tanks connected to a holding tank, it is not ordinarily necessary to provide for 100 per cent storage of all cyanide solution in use. Aside from the law of probability involving a spill of cyanide from more than one tank at a time, other design factors are: relative size of tanks, concentration of cyanide solution, and availability of dilution in municipal sewers or receiving stream. Where less than 100 per cent holding capacity is available, a high-level alarm system, installed in the holding tank, is recommended. Under special circumstances, the Stream Pollution Control Board has approved designs providing for holding capacity as low as 50 per cent of the solution volume in use.

By means of special piping and compartmentation of holding tanks, this type of installation is able to recover and reclaim valuable spilled solutions.

Pits or Recessed Floor Areas

A positive method of isolation is the pit method, where a below-floor-level pit is provided directly under each cyanide tank (Figure 3). This method is favored in new installations of automatic plating units.

Double-Capacity Tanks

A double-capacity tank installation involves the placing of a holding tank around a cyanide tank, but to be adequate in size the volume of the outer tank should be twice the volume of cyanide in use. The extra volume is to retain cyanide solution overflow as well as leakage (Figure 4).

Mere double-walled tanks do not qualify as satisfactory if the volume of air space between tanks is not equal to or greater than the cyanide solution in use.

Double-capacity tanks are especially useful where only one small tank is involved or where a tank is in such a

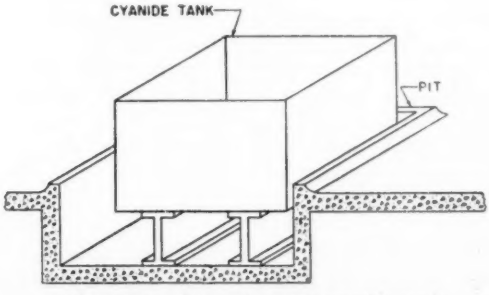

FIGURE 3.—Pit underneath cyanide tank.

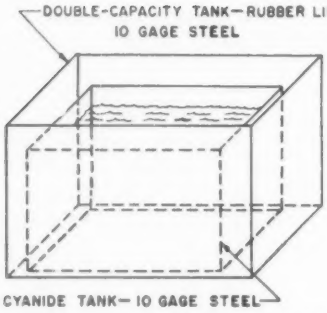

FIGURE 4.—Double-capacity tank for retaining a tank overflow or leakage.

position that isolation by other methods cannot be applied.

Miscellaneous

One method of cyanide isolation generally used in small operations is to design the plating area with no floor drains. Plants using the method have thus complied with the regulation without any construction. Rinse waters, of course, are piped directly to a sewer removed from the area. Any accidental spill will be retained on the floor and, incidentally, more than likely interfere with production until removed.

Several plants have constructed ramps across doorways to isolate an entire plating area.

In this category might also be included the scheme of constructing a waterproof riser over a floor drain in an isolated area to afford storage of spilled cyanide. A few such vertical sewer extension installations have been reluctantly approved where economy was favored over increased risk. Such installations are too easily removed or circumvented, but the real danger lies in the possibility of a cyanide spill reacting with a spilled acid solution to produce deadly hydrogen cyanide gas in the working area.

Cyanide Solution Disposal

Many times the question is asked, "If we have an accident and the solution is retained, what do we do with it?" In most cases, the solution will have become contaminated and therefore require disposal.

Simple controlled bleeding of the solution into a sewer or stream seems to be the most economical method, but extreme care must be exercised. Careful determination of the volume and cyanide concentration must be made. An accurate knowledge of the volume of diluting sewage or stream is a "must." The municipal sewer superintendent or sewage treatment plant operator should be consulted, or at least advised of the proposed disposal. He will generally recommend that the cyanide, as CN, be limited after dilution in raw sewage to the range of 1 to 3 p.p.m.

The sewage treatment plant operator should keep in mind that such solutions might have a high alkalinity, high pH, and contain metals such as cadmium, copper, and zinc. Discharge of metallic sludges from plating plants into sewers should be avoided. If the cyanide solution is to be bled into a stream, the recommendation is that the cyanide concentration, as CN, after mixing and dilution, be not greater than 0.2 p.p.m. Before mixing has been accomplished, a toxic streak might exist below the point of discharge.

Pretreatment is in order at times. This might be accomplished by chlorination, hypochlorination, or electrolytic oxidation—details of these processes can be found in the technical literature.

Indiana experience shows that rinse-water treatment is necessary in but relatively few places. Ten plating plants have facilities for treatment. Rinse-water treatment methods employed thus far are alkaline (gas) chlorination and hypochlorination.

Costs

The cost of complying with the regulation naturally depends upon the size of the operation and the local condi-

tions. A broad estimation of cost for the run-of-the-mill curbing job ranges from $200 to $700. Most holding tank installations with appurtenances range from $2,000 to $10,000.

Summary

Progress made in the past year covering cyanide disposal has been gratifying. Cyanide is used in 235 plants, of which 215 have been inspected. Up to June 1954 the Stream Pollution Control Board had approved existing and planned facilities at 194 plants. No construction was necessary at 72 plants. Of the 122 plants where construction is necessary, 75 have completed facilities; 20 more are under construction and the remaining 27 are in the planning stage.

Construction and proper maintenance of facilities have already substantially reduced accidental discharges. In the first five months of 1954 there were five reported occasions where accidents involving cyanide solutions were averted by preventive installations.

The regulation has greatly improved working relations between industrial sewer users and sewage treatment plant operators. All concerned are now more aware of the problems of cyanide disposal and their proper solution. Several potentially dangerous situations have been revealed and corrected where large quantities of cyanide solution existed upstream from public water supply intakes. An idea of the potential is revealed when it is learned that a total of 450,000 gal. of cyanide solutions are scattered throughout the state.

In conclusion, it cannot be overemphasized that the Stream Pollution Control Board and the engineers of the State Board of Health have received splendid cooperation from industry in bringing this phase of stream pollution abatement under control.

REVIEW OF METHODS FOR CYANIDE DETERMINATION IN SEWAGE *

By Daniel F. Krawczyk

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Cyanides are the unique combination of an attached nitrogen and carbon atom with a free bond for another cyanide, a metallic, or a non-metallic type linkage. Organic compounds with a cyanide type linkage are usually called nitriles or cyanogen compounds. Cyanides are not naturally occurring substances, but they can be obtained from fermentation of certain glucosides that occur in bitter almonds, cherry laurel leaves, cherry kernels, and other products found in nature (1).

The extremely poisonous qualities of hydrocyanic acid were known to the ancient Egyptians. However, it wasn't until 1782 that the chemical composition of hydrocyanic acid was recognized. This chemical is still used by some penal institutions to carry out capital punishment sentences (1).

Cyanides usually will not be found in sewage treatment plants as a result of some natural decomposition. If and when cyanides are detected in the raw sewage of a treatment plant, they are there as a result of some industrial waste discharge. Plating wastes, fumigation wastes, coke plant wastes, and some organic chemical wastes are possible sources of cyanides in raw sewage.

An abnormal rise in the chlorine demand of raw sewage may be the first indication of cyanide content. However, a high chlorine demand is not always caused by cyanides. Cyanide that exists as hydrocyanic acid will react with chlorine to form cyanogen chloride, but the formation of cyanogen chloride is not a solution for the elimination of cyanides because this volatile substance is as toxic as hydrocyanic acid.

Besides reacting with the chlorine, which should be used for disinfection and treatment, cyanides may adversely affect digestion and secondary treatment facilities. If large quantities of alkaline cyanide wastes are discharged to sewers, they are also a potential health hazard, especially to any sewer service crews working in the vicinity of the discharge. High concentrations of cyanides definitely have no place in the sewer system.

The presence of cyanides in an effluent discharge is of vital importance. A concentration of 0.1 p.p.m. cyanides is known to be toxic to some species of fish. Thus, every sewage treatment plant operator should have some idea of the concentration of cyanides leaving the plant (2).

Methods of Determination

Analytical methods for the determination of cyanides are not new, for they have been available from the very infancy of modern chemistry. However, good accurate methods that are capable of detecting a concentration of 0.1 p.p.m. are few.

The Liebig titration perhaps is the oldest quantitative method for the determination of cyanides (1). This procedure involves the titration of the cyanide radical in an alkaline solution with a known concentration of silver nitrate solution. The silver ion will react with the cyanide to form a com-

* Presented at 1954 Spring Meeting, New York Sewage and Industrial Wastes Assn.; Syracuse, N. Y.; June 14–15, 1954.

plex silver cyanide salt which is soluble in alkali. When all the cyanide is complexed, then addition of excess titrant will cause the precipitation of the simple silver cyanide. The first formation of the precipitate is the end point of the titration. This method requires preliminary treatment of the sample to eliminate turbidity so that the first opalescence indicating the end point may be readily observed. Investigators have proposed the use of an internal indicator, para-dimethyl- aminobenzylidene-rhodanin, which changes color when an excess of a heavy metal (such as silver) is present (3).

In using the Liebig method a known amount of sewage is acidified with a non-volatile acid and about two-thirds of the sample is distilled over into a measured amount of 2 per cent caustic with the distillate discharging below the liquid level in the receiver. The cyanides determined in this manner are the so-called free cyanides, which would exert a chlorine demand, and also the greater portion of the complexed cyanides. The Liebig method can be used for concentrations from 0.1 p.p.m. and up if extreme caution is used in all phases of the analysis.

Fasken (4) has recommended the thiocyanate method for the determination of cyanides in water. The analysis consists of reacting the cyanide with a sulfide to form a thiocyanate, with subsequent conversion of the thiocyanate in the presence of ferric ion to a red-colored ferric thiocyanate. In using this procedure for sewage the manipulations are time-consuming. With the proper analytical technique the Fasken method will give good reproducible results from 0.1 p.pm. and up.

The reaction of a cyanogen halide with an aromatic amine and pyridine to produce colored products furnishes the basis for the analytical procedures to measure cyanide content proposed by two groups of investigators. The one method using pyridine and benzidine was first advanced by Aldridge (5) and modified by Nusbaum and Skupeko (6). A second method employs pyridine pyrazolone reagent and was first suggested by Epstein (7). The Nusbaum and Skupeko modification of Aldridge's method permits determination of cyanide directly in the sample without distillation and extraction of the colored product in butyl alcohol. All other methods advocate and emphasize the necessity of pretreatment of the sample to remove colored, colloidal, and interfering substances.

Determining cyanide in sewage directly is said to be objectionable for the following reasons:

1. Sewage has suspended matter and colored material which will interfere with the observation of the colored end-products.
2. Even though the sewage is filtered, colloidal and colored substances will still remain in the filtrate.
3. When the sewage is filtered some of the cyanides may be lost because of the volatility of the hydrocyanic acid.

Color may be developed directly in sewage with either the pyridine-benzidine or the pyridine-pyrazolone method. However, if the sewage has inherent color the foregoing could serve only as a qualitative analysis. In order to effect a quantitative determination in sewage, a sample should be filtered to remove suspended matter. One portion of the filtered sewage is chlorinated to a 0.1-p.p.m. residual (ortho-tolidine) and made alkaline with caustic (pH 10 or above) to destroy the cyanides. To this first portion the reagents are added, as well as to a second portion merely chlorinated to a 0.1-p.p.m. residual. A comparison of the two portions (visually, colorimetrically, or photometrically) against standards prepared in the same manner will afford a measurement of the concentration of simple cyanide salts present.

One of the most effective ways to destroy cyanides is chlorination in alkaline medium. Thus, if chlorine is added to obtain a residual and then sufficient alkali is introduced, cyanides present will be destroyed. A sample treated in the preceding manner will provide a blank for comparison purposes that will exclude all substances tending to give false cyanide results.

After studying the aforementioned methods for the determination of cyanides in sewage, efforts of the laboratory staff of the Buffalo Sewer Authority were directed towards revising the procedures with a view to reducing the time element and adopting a more rapid control analysis method. The detail as worked out for the three main types of analyses discussed is outlined in the following paragraphs.

Liebig Titration Method

Reagents

Chlorine water—pass chlorine gas through water so that a solution of slightly more than 1 g. of chlorine per liter is produced (8).

Ortho-tolidine reagent—Dissolve 1.35 g. ortho-tolidine dihydrochloride in 500 ml. distilled water. Add this solution with constant stirring to 500 ml. dilute HCl, prepared by mixing 150 ml. concentrated HCl with 350 ml. distilled water (8).

p-Dimethyl-aminobenzylidene-rhodanin (indicator) solution—Dissolve 0.02 g. of this reagent in 100 ml. acetone.

Silver nitrate solution 0.0192 N—Dissolve 3.27 g. $AgNO_3$ in 1 l. distilled water. This reagent should be standardized.

Sodium hydroxide solution, 10 per cent—Dissolve 100 g. NaOH in 1 l. distilled water.

Procedure

Procure a composite sample of raw sewage. To at least a 200-ml. portion add chlorine water until a 0.1-p.p.m. residual is obtained with O.T. reagent as indicated by spot plate test. Add 2 ml. 10 per cent sodium hydroxide, agitate for a few seconds, and add 1 ml. indicator solution. Titrate the solution with 0.0192 N silver nitrate solution until there is a color change from yellow to salmon pink. With this titration as a blank, the milliliters of silver nitrate used should be designated as B (blank).

To another similar portion add 2 ml. of 10 per cent sodium hydroxide solution and 1 ml. of indicator solution, and titrate with 0.0192 N silver nitrate solution until the salmon pink coloration is of the same depth as attained with the blank titrations. The milliliters of silver nitrate used in this second titration should be noted as A.

Calculations

$$\text{Conc. of cyanides, in p.p.m.} = \frac{A - B \times 1{,}000}{\text{Size of Sample}}$$

As is readily noted, the Liebig method is strictly a titration method and does not require utilization of color standards or equipment, which may not be available in some treatment plants.

Other Methods

The next point of study uses the possibility of determining cyanide concentrations colorimetrically without resorting to distillations, extraction, or some other manipulations.

Filtrations of sewage samples appeared to be the only other alternative. However, ordinary filter paper will not eliminate colloidal turbidity and the filter paper may absorb some of the cyanides. Moreover, hydrocyanic acid is a very volatile liquid (boiling point 25.8° to 26.7° C.) Likewise, cyanogen chloride is a very volatile liquid (boiling point 12.5° to 13° C.) Thus, some of the cyanides may be lost

and the error magnified when a chlorinated sample is filtered.

The benzidine-pyridine method can be used as a qualitative method. Development of an orange coloration in 100 ml. of sample will indicate the presence of at least 0.1 p.p.m. cyanides. For quantitative determinations the standards for visual or photometric comparison should be filtered before any chemicals are added.

Benzidine-Pyridine Method

Reagents

Chlorine water—Prepare as in previous method.

Ortho-tolidine reagent—Prepare as in previous method.

Sodium arsenite solution—Dissolve 2 g. analytical reagent in 100 ml. distilled water.

Pyridine solution—Dissolve 25 g. pyridine in 75 ml. distilled water and acidify with 2 ml. concentrated hydrochloric acid.

Benzidine hydrochloride solution—Dissolve 2 g. analytical reagent in 100 ml. distilled water.

Pyridine-benzidine mixture—To 5 ml. pyridine solution add 0.3 ml. benzidine hydrochloride solution, mix, and add to the sample immediately.

Phosphoric acid, 10 per cent—Add 100 g. phosphoric acid to 1 l. distilled water.

Sodium hydroxide solution, 10 per cent—Prepare as in previous method.

Procedure

Filter sufficient sample so that 100 ml. can be used for a blank and another 100 ml. for color development. To both portions add chlorine water to a 0.1-p.p.m. O.T. residual. To one portion add 2 ml. of 10 per cent sodium hydroxide solution, agitate for a few seconds, neutralize with 2 ml. of 10 per cent phosphoric acid, and add 4 drops of 10 per cent sodium arsenite solution. To this first portion add the mixed (pyridine-benzidine) reagent and consider this as the blank. At the same time add 4 drops of sodium arsenite solution and the mixed reagent to the second portion. Compare immediately the color of the second portion with the blank against the standards visually, or photometrically at 525 mμ., for the color fades rapidly.

Pyridine-Pyrazolone Method

Reagents

Chlorine water—Prepare as in previous method.

Ortho-tolidine reagent—Prepare as in previous method.

1-Phenyl-3-methyl-5-pyrazolone—Prepare a saturated solution of pyrazolone (solubility 0.5 g. per 100 ml. of water) by adding the reagent to distilled water at 75° C. Cool the solution and agitate occasionally while cooling.

Pyridine—Reagent grade.

3,3′ Dimethyl-1,1′ diphenyl-(4,4′ bi-2 pyrazoline)-5.5′ dione bis-pyrazolone—Eastman Kodak reagent grade No. 6969.

Mixed reagent—Mix 125 ml. of filtered saturated solution of pyrazolone with a filtered solution of 25 ml. pyridine containing 0.025 g. bis-pyrazolone.

Phosphoric acid, 10 per cent—Prepared as in previous method.

Sodium hydroxide solution, 10 per cent—Prepared as in previous method.

Procedure

Filter sufficient sample so that 50 ml. can be used as a blank and another 50-ml. portion for color development. To the two portions add chlorine water to a 0.1-p.p.m. O.T. residual. To one portion add 2 ml. of 10 per cent NaOH solution, stir for a few seconds, neutralize the acid with 2 ml. of 10 per cent phosphoric acid, and consider this as the blank. To both portions add 5 ml. of mixed reagent and

allow 20 min. for full color development. After 20 min. compare the color developed in the sample with the blank against standards prepared in the same manner. Comparison can be made visually or photometrically. When using a photometer, a 620-mμ. wave length is used for color comparison. If the color developed is too deep for comparison, aliquot portions of sewage must be used.

Summary

After reviewing the methods for determination of cyanides, modifications are suggested so that low concentrations of simple cyanide salts can be determined directly in sewage. The procedures described are for control purposes. To determine the total cyanide (that is, the simple cyanide salts and the metallic complexed salts) other procedures must be used.

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1954 SHELLFISH SANITATION CONFERENCE

Almost 100 representatives of federal, state, and Canadian health and fisheries agencies and of the shellfish industry on September 9–10, 1954, attended the first national conference on shellfish sanitation in almost 30 years. The conference was called by the Surgeon General of the U. S. Public Health Service to discuss problems of both domestic and international significance.

On the domestic side, it was agreed unanimously that the voluntary cooperative federal-state-industry sanitation control program be continued, with certain technical changes, but essentially in its present form. Under this system the states assume primary responsibility for sanitation of shellfish production and processing. The USPHS will continue to develop uniform standards, and evaluate and endorse the state programs that meet its standards.

Among the many factors brought into focus at the meeting were those of pollution control of waters used for shellfish propagation, new methods of merchandising, developments in new freezing methods, and location of repacking and freezing plants. New freezing techniques give rise to the international problems as dollar-short countries with shellfish surpluses are eager to take advantage of these developments to help stabilize their economies. Industry representatives, therefore, expressed the view that the same rigid controls that have been placed over domestic producers also should be applied to foreign producers.

DESIGN OF A CONTINUOUS AUTOMATIC SAMPLER FOR DEEP SEWERS

By Jerome Wilkenfeld

Technical Supervisor, Hooker Electrochemical Company, Niagara Falls, N. Y.

In the course of pollution abatement work at the Hooker Electrochemical Company, Niagara Falls, N. Y., it became apparent that, in addition to the normal sampling of process effluents, continuous sampling of effluent streams on a 24-hr. basis would supply additional valuable information on over-all conditions in the plant. Since the major proportion of the products produced at the plant are organic in nature, it was felt advisable to construct a sampler so that a 24-hr. composite sample could be collected of suitable size for extraction purposes, this sample to be collected directly in a bottle that could be handled in the laboratory without transferring. With this in mind a continuous automatic sampler was designed and installed on the main sewer leaving the plant. This sewer is located approximately 20-ft. below grade and has a relatively steady flow.

The first sampler built attempted to use a positive displacement pump located above ground with a long suction line extending down into the sewer. Pump life was extremely short, however, because even small amounts of suspended solids caused sufficient wear to reduce the pump suction below the required amount. Plastic pump parts failed due to absorption of trace amounts of organic solvents, which caused swelling. In addition, unless a pump received almost immediate attention when it lost its prime, the pump burned out due to running dry at the relatively high speeds required for operation. In all, three types of positive displacement pumps were tried.

Collection of relatively small samples at frequent intervals with a system of timers and valves also caused frequent shutdowns due to plugged valves and timer failures.

With these limitations in mind, it was decided that a pump that would operate with a minimum suction lift and at a low speed would be most suitable. At the same time, most of the pumping equipment must be kept out of the sewer, due to the hazards of sewer atmospheres. It was also felt that the sample collection itself should be carried out without the use of timers or valves and yet sample size and frequency had to be closely controlled.

Sampler Description

Such a sampler has been developed, and has been in operation since 1951 with only minor modification. This sampler is reliable, rugged, and capable of operating for long periods with a minimum of maintenance. Five of the samplers are now in use in the plant; four are considered semi-portable and are moved to branch sewers as desired to assist in determining the quality of effluents in localized areas.

The schematic layout of the sampling equipment is shown in Figure 1, the complete unit in Figure 2. The principal of operation consists of using a deep-well pump, with the cylinder located just above the water level, to pump a continuous stream of approximately 5 g.p.m. of water from the sewer. This stream is piped over a

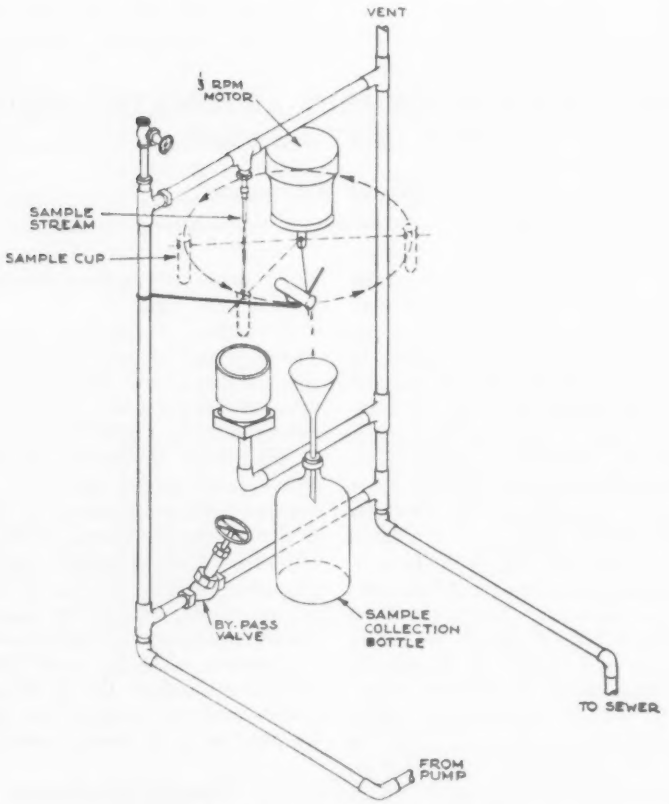

FIGURE 1.—Layout of sampling equipment.

sampling tap, which is allowed to flow continuously to a drain cup. All water not taken as a sample is returned to the sewer through a drain line. Mounted adjacent to the sampling tap is a ⅓-r.p.m., 110-v. motor carrying a 3-cc. glass sample cup pivoted from the top. In the course of the rotation, the cup passes through the falling stream of water and is then tripped by a rod, dumping the sample into a collection bottle. The deep-well pump used has a 6-in. stroke and is modified to use a two-leather differential plunger seal. The cylinder used is a brass-lined artesian well cylinder with 10-in. stroke and $^{13}/_{16}$-in. inside diameter.

It should be noted that all piping is of 310 stainless steel and that the box containing the pump and sampler is mounted on a pedestal base to allow air circulation between the manhole cover and the equipment. This was done when it was found on previous types of samplers that flush mounting caused excessive corrosion due to moisture condensation from sewer breathing. An additional advantage is the accessibility of the well line coupling allowing disconnecting and removal of the well line without disturbing the pump and housing.

Advantages of Sampler

In effect, a portion of the sewage stream is brought above ground to the

sampler. The sampler can be further modified to handle other situations. The sample size is easily adjusted by changing the cup size, while the frequency of sampling is changed by use of a different speed motor. Should the collection of samples by periods be desired, a timer-actuated sampling table can be added.

Unit described has the following advantages:

1. It is a slow-speed machine with no delicate timers or valves which are susceptible to fouling.

2. The construction of the pump and sampling mechanism allows satisfactory sampling of streams containing suspended solids or other miscellaneous materials.

3. The sample is rapidly delivered from the stream with little time lag, should this be advantageous (as in the case where a record or control of pH is desired). This is done on one installation in the plant, where the sampler is used for sampling purposes and for pH recording simultaneously.

4. Maintenance on the equipment is

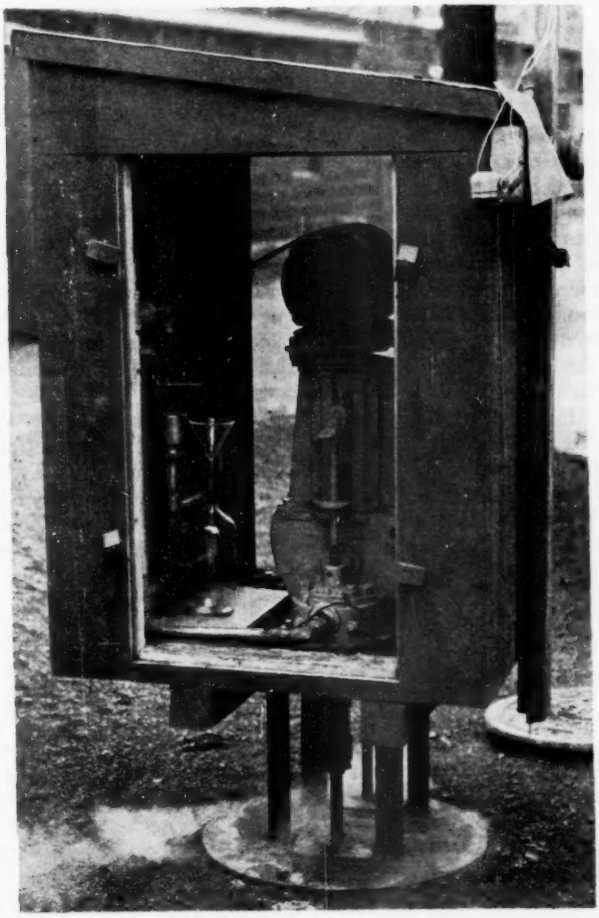

FIGURE 2.—Method of housing and locating sampler on sewer.

low, with the pumping head requiring only occasional lubrication. The cylinders last upwards of three months, depending on the location and the type of sewage handled. On occasion, when feed lines have been blocked, the pumps have run dry for periods of more than 18 hr. without any apparent injury. Several sampling motors have been in service for over a year without any repairs being required.

In general, it has been found that this type of sampling equipment is not only adaptable to many types of sampling problems, but also is ideally suited for sampling from deep sewers or other relatively inaccessible locations. The ability to handle streams containing solids without plugging, together with the mechanical reliability, make this a suitable sampler where operation with a minimum of attention is desirable.

SHELTERED HARBOR POLLUTION FROM SMALL BOATS

Pollution from cabin cruisers and other pleasure craft when moored in small sheltered harbors is a matter of concern to public health officials from the standpoints of both human health and shellfish propagation according to a recent paper. The paper, by William T. Ingram and Alexander Diachishin, was presented at a recent meeting of the American Society of Civil Engineers in Atlantic City, N. J.

A study during the 1953 yachting season showed that waste from pleasure boats using a sheltered harbor polluted the waters above the requirement set for safe culture of such shellfish as clams. In addition, bathing in water adjacent to craft in a sheltered harbor is aesthetically undesirable and may be hazardous to individuals. Poorest water conditions were found during the low ebbing tide. Such factors as depth, tidal movement, boating activity, position of craft with respect to bathing areas and shellfish beds, air temperature, wind direction and velocity, weather, water temperature, and presence of floating solids were considered.

The investigation was sponsored by the Research Division, College of Engineering, New York University, and the Interstate Sanitation Commission. The New York State Conservation Department cooperated in the necessary sampling.

Stream Pollution

ANALYSIS OF A STREAM'S CAPACITY FOR ASSIMILATING POLLUTION—A DISCUSSION

By Thomas R. Camp

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The paper on "Analysis of a Stream's Capacity for Assimilating Pollution," by M. A. Churchill (1), is a milestone in the development of sanitary engineering practice for the control of pollution. In the writer's opinion this contribution is no less valuable than the original work of Streeter and Phelps relating to the oxygen balance in streams.

The principal obstacle to the rational determination of allowable pollution loads by the pollution control agencies has been the difficulty and expense of measuring in the field the time of flow of a stream between successive sampling stations. In order to evaluate the so-called deoxygenation constant, k_1, the reaeration constant, k_2, and the bottom deposit constant, k_3, for any reach of a stream, it is necessary to know the time of flow for one or more rates of discharge. It is routine practice for most pollution control agencies to determine the water temperature, the D.O., and the B.O.D. of grab samples collected periodically from established sampling stations; and the rate of discharge at the time of sampling can usually be estimated from the records of nearby gaging stations. It is rare indeed, however, for the control agencies to determine the time of flow between sampling stations. The Churchill method permits the evaluation of allowable pollution loads from the data normally obtained by the pollution control agencies without any knowledge of the time of flow between stations.

The key to the Churchill method is the plotting of dissolved oxygen regression lines for each sampling station. In these graphs the drop in dissolved oxygen between the sampling station above pollution and the one under consideration is plotted against the B.O.D. load of the stream per unit of discharge at the sampling station under consideration. If the data used for the regression lines are carefully selected as to temperature so that the family of curves represents a relatively narrow water temperature range, the oxygen regression lines represent the result of all the reaction rates within the temperature range considered. The writer believes that the regression lines are more reliable than the reaction rate constants determined from the same data, particularly if statistical methods are used for the regression lines, as was the case in Mr. Churchill's example. One of the variables, time, is automatically included without the necessity of its having been measured. Thus the error involved in the measurement of the time of flow is eliminated. Since the dissolved oxygen regression lines for each station have been plotted throughout the range of discharge rates occurring in the stream at the times of sampling, the regression lines may be used as basic data for the plotting of dissolved oxygen profiles for various rates of

discharge with normal loading or for various pollution loads for minimum stream flows, as has been illustrated by the author. The allowable pollution loads may be established directly from the water quality standards and the dissolved oxygen profiles.

An approach to the Churchill method was developed by LeBosquet and Tsivoglou (2). These authors plotted the critical dissolved oxygen content in the Cincinnati pool of the Ohio River against the rate of discharge of the river. In utilizing this graph it was assumed that the pollution load was constant, in which case a reduction in pollution load would produce the same increase in critical dissolved oxygen content as would be produced by an equivalent increase in the rate of river discharge. The LeBosquet-Tsivoglou method is much simpler than the Churchill method, but it takes no account of residual upstream pollution or of the variation in D.O. content upstream from the point of pollution under consideration. The critical dissolved oxygen used in the plotting reflects variable pollution loads within the pool, variable residual pollution upstream from the pool, and variable dissolved oxygen content upstream from the pool. Failure to take account of these variables is apt to result in large errors in computing allowable pollution loads. The Churchill method is free from these sources of error.

The writer hopes that the Churchill method will be widely publicized to the end that it may be adopted generally in the routine work of the pollution control agencies. The polluting municipality or industry is entitled to know the amount of pollution which will be permitted; it must know its allowable pollution load in order to arrive at a rational and economical design of its pollution abatement works. The pollution control agencies are now in a position to furnish this information to the polluters with relatively little effort and expense.

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THE OPERATOR'S CORNER

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CARD RECORD SYSTEMS FOR PREVENTIVE MAINTENANCE *

I. Introduction

BY JOHN T. NORGAARD

Civil Engineer, Brown and Caldwell, Consulting Engineers, San Francisco, Calif.

In any preventive maintenance program, whether in a small or large treatment plant, systematic organizing, scheduling, and recording of the work is necessary if the program is to succeed. One such system, which originated in public water utility practice and was adopted for water and sewage works by the U. S. Army and Air Force, has recently been described by Sanders (1). Application of this system in civilian practice by the Minneapolis-St. Paul Sanitary District (2) and at three plants of the Hampton Roads Sanitation District (3) also have been recently discussed. The purpose of this symposium is to describe briefly the simplicity of the preventive maintenance record system for water and sewage works prescribed in U. S. Army manuals (4) (5), and to demonstrate its adaptability to large as well as small sewage works. A further purpose is to describe improvements to the card forms, including edge-punched cards, used to schedule and record each step in a maintenance program.

Of several modifications of the card record system employed at municipal sewage treatment plants, edge-punched cards offer advantages for all but the smallest installations. Such cards make possible rapid sorting into any grouping desired and the selection of individual cards, even though filed without regard to order.

For those not familiar with this type of record system, a hand-sorted punched card has one or more rows of holes prepunched along each edge, while the face and back of the card are used for a written record of the desired data. Each hole or combination of holes along the edges is assigned a specific meaning. To designate, for example, a semiannual service, the paper between the edge of the card and the hole marked "semiannual" is removed with a hand punch, thus forming a notch. To select this card from a pack of cards, and all others calling for a semiannual service, the pack is aligned in a vertical position with the desired hole in the upper edge. As indicated in Figure 1, a needle similar to an ice pick is then passed through the hole. Upon fanning out the pack and lifting it with the needle, all cards notched in the selected position drop from the pack, while those not notched remain suspended from the needle.

* Presented at 26th Annual Convention, California Sewage and Industrial Wastes Assn.; Sacramento, Calif.; May 5–8, 1954.

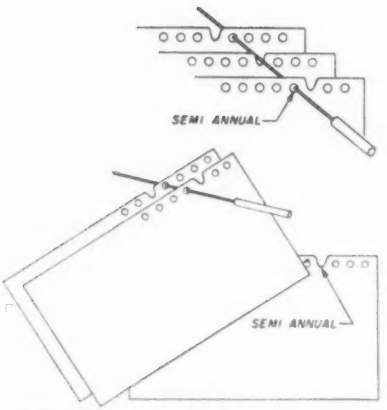


FIGURE 1.—Principle of edge-punched card record system for maintenance programs.

Other papers of this symposium describe ways in which edge-punched cards are used to facilitate the preventive maintenance program at two moderately-sized sewage treatment plants. At large plants, having a more complex preventive maintenance program with respect both to number and variety of equipment and to supervision of the work, further coding would undoubtedly prove advantageous. For example, coding each card for the grade of lubricant required for the equipment it serves would enable a rapid check on the total number of grades and an estimation of the quantity of each grade needed annually. For those interested in exploring the possibilities of edge-punched card record systems, reference is made to the volume on this subject edited by Casey and Perry (7).

Although this symposium is directed primarily to preventive maintenance in sewage treatment plants, the card record applies equally well to outlying pumping stations, interceptors, and outfall works. Wherever a routine program of sewer inspection, cleaning, and repair is practiced, as it is in a growing number of cities, the card record also may be used advantageously in the collection system maintenance program.

II. Application of Edge-Punched Cards at Santa Rosa

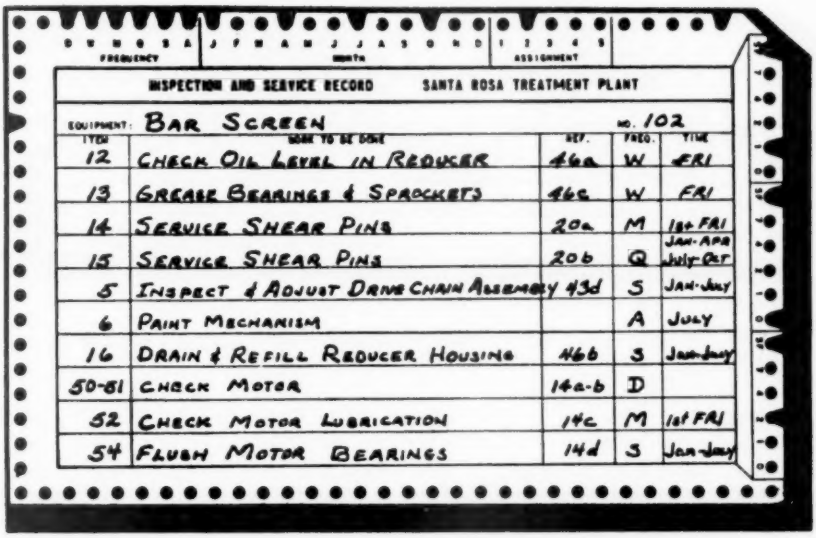
By Murray B. McKinnie

Superintendent, Sewage Treatment Plant, Santa Rosa, Calif.

The Santa Rosa sewage treatment plant is not unique in having numerous pieces of mechanical equipment that are in constant need of preventive maintenance. The plant is designed for a flow of 5 m.g.d. and consists of pre-aeration and sedimentation followed by trickling filters, secondary sedimentation, and ponds. Pumping and air production is by gas engine.

The system of preventive maintenance records uses punched cards 5 in. by 8 in. in size. These cards are in most respects the same as those shown in the Army Training Manual (4), each card being set up, as far as possible, according to the manual. In order to number each piece of equipment the plant was divided into areas, with each area assigned a number in the 100 series. As an example, all the primary sedimentation and pre-aeration equipment is in the 200 series. In each area there were sufficient numbers available so that all equipment could have individual numbers. The only pieces of equipment that do not have individual cards are the valves; although each valve has a number, each type of valve is on one card with the total number of valves of this type noted on the card.

A description of how these cards are coded and used will in all prob-



INSPECTION AND SERVICE RECORD SANTA ROSA TREATMENT PLANT

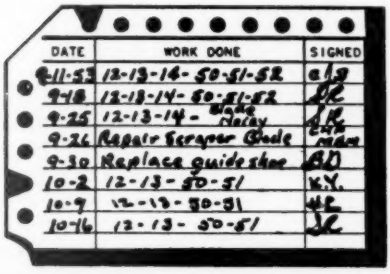
EQUIPMENT: BAR SCREEN NO. 102

ITEM	WORK TO BE DONE	REF.	FREQ.	TIME
12	CHECK OIL LEVEL IN REDUCER	46a	W	FRI
13	GREASE BEARINGS & SPROCKETS	46c	W	FRI
14	SERVICE SHEAR PINS	20a	M	1st FRI
15	SERVICE SHEAR PINS	20b	Q	JAN-APR JULY-OCT
5	INSPECT & ADJUST DRIVE CHAIN ASSEMBLY	43d	S	JAN-JULY
6	PAINT MECHANISM		A	JULY
16	DRAIN & REFILL REDUCER HOUSING	46b	S	JAN-JULY
50-51	CHECK MOTOR	14a-b	D	
52	CHECK MOTOR LUBRICATION	14c	M	1st FRI
54	FLUSH MOTOR BEARINGS	14d	S	JAN-JULY

FIGURE 2.—Front of typical edge-punched card for preventive maintenance record on equipment.

ability help operators who would like to set up such a system. Figure 2 shows a typical card from the card file. Figure 3 shows a portion of the reverse side of this card as filled out by the operators. Some of the plant equipment is not as listed in the manual and the cards are adapted to an hourly frequency of maintenance.

From Figure 2 it can be seen that the holes on the top and right-hand edges are used almost exclusively. After naming and numbering the pieces of equipment the various items of work to be done are listed on the card. Along with each item of work is an item number, reference number,



DATE	WORK DONE	SIGNED
9-11-53	12-13-14-50-51-52	CLB
9-18	12-13-14-50-51-52	JR
9-25	12-13-14 - Bank Holiday	JR
9-26	Repair Scraper Blade	CLB
9-30	Replace guide shoe	CLB
10-2	12-13-50-51	K.Y.
10-9	12-13-50-51	JR
10-16	12-13-50-51	JR

FIGURE 3.—Portion of reverse of typical edge-punched card for preventive maintenance record on equipment.

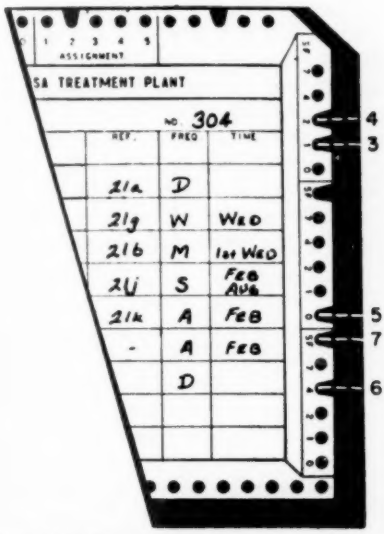


FIGURE 4.—Method of punching equipment number (304).

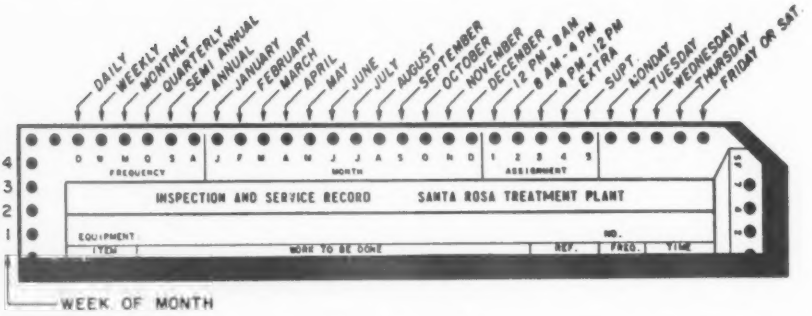


FIGURE 5.—Use of code to show week of month, frequency, month, assignment, and day of week.

and frequency. In most cases these figures refer to the Army Manual (4). The time column on the right of the card is filled in with each area, as far as possible, having work done on a different day of the week. This spreads the work out sufficiently so the operators are able to do most of the work that comes up. When all the cards have been made up and have been checked, the equipment numbers are punched out on the right-hand edge (Figure 4). The holes along the top edge are then punched according to the coding (Figure 5). To show the adaptability of these cards it was found after the cards were printed that it was necessary to indicate the week days as well as the week of the month on the card. The holes on the extreme right of the top edge were used for the week days while the top four holes on the left-hand edge were used for the week of the month.

With this system it is easy to locate the card for a certain piece of equipment and then to know what to do on this equipment. When filled in on the reverse side by the operator or whoever does the work, a record is obtained that can show which equipment takes the most maintenance and repairs.

It is not possible to remember each and every grease fitting of all the equipment and it is especially hard to remember how often the equipment should be serviced. Usually the fitting in the inaccessible place is the one that is neglected and it isn't long before a breakdown occurs because of lack of grease or oil. Some means to tell when and what should be done on each piece of equipment is a necessity for proper operation of a sewage treatment plant. The system described is about as simple a one as there is for a small plant.

III. Application of Edge-Punched Cards at Menlo Park

By Warren R. Uhte

Office Engineer and Chief Operator, Menlo Park Sanitary District, Menlo Park, Calif.

The Menlo Park Sanitary District's sewage treatment plant was put into operation in November 1952. It is a primary treatment plant with a design capacity at average flow of 4 m.g.d. The plant includes a large automatic pumping station, some 4,000 ft. of 24-in. force main, automatic bar screen,

automatic grit removal channel, pretreatment tanks with mechanical aeration and scum removal, rectangular sedimentation tanks with both longitudinal and cross collectors, two digesters capable of operating either in one- or two-stage digestion and equipped with external heating and recirculation, and a complete chlorination system with provisions for both pre-chlorination and post-chlorination. The plant is operated 16 hr. a day 7 days a week with a crew of four plus a part-time laborer. The three plant operators work regular shifts, so arranged that on Wednesdays there are two operators on duty during the day.

Soon after the plant was placed in operation it became apparent that some special form of schedule was needed for routine lubricating, inspecting, and checking. Although a daily schedule had been posted, work which did not fall into the everyday category received only hit-and-miss attention, resulting most commonly in over-lubrication and the drying up of the water seal on the digester's floating cover combination flame trap and pressure reliefs. A simple, easily adaptable system for scheduling preventive maintenance had to be found for everyday use in the plant.

A copy of the card used at the Santa Rosa plant was obtained, together with a brief description of its method of use.

Using the sample Santa Rosa card as our only guide, the steps necessary for carrying out a similar system at Menlo Park were found to be as follows:

1. Setting up a numbered file for the whole plant.
2. Listing all equipment and structural units with their required type of preventive maintenance.
3. Setting up the actual scheduling of the work required.
4. Procuring and printing the cards.
5. Putting the system into operation.

Establishment of a numbered file for the whole plant seemed at first to be a formidable task, but proved surprisingly simple when finally attempted. By following the direction of flow through the plant and numbering the major structural divisions consecutively, the numbered file fell into place easily. For example, all pumping station items are in the 1,000 group, force main 2,000, inlet works 3,000, pre-treatment tanks 4,000, sedimentation tanks and control building 5,000, chlorination system 6,000, water well and reservoir 7,000, operations building including boiler room 8,000, and digesters 9,000. These then are the master numbers under which all equipment and structural maintenance information for each division is filed. Four-digit numbers were chosen because of necessary sub-divisions of main units, and also because they gave added room for growth of the filing system. This allowance for sub-divisions has proved especially useful in the case of the operations building, where the laboratory, garage, boiler room, and others all have their own file number series, while the requirements of constant additions of new equipment under different master numbers has been easily met by just using the left-over numbers of the series. An up-to-date listing of all file numbers for the complete plant is kept on the main office desk, where it is easily available for quick reference. All manufacturers' data and other information are kept in office files under the file number listed for the equipment. Through quick reference to the master listing, any operator can quickly pull from the files all the available information on any desired equipment or structural unit.

With the master numbers selected, it then became a task of finding the exact type of preventive maintenance required by covering each structure individually and listing each equip-

Operations Building—Downstairs—Air Compressor 8250

8 2 50

	Sub-File Number	Frequency	Approx. Completion Time
1. Clean and re-grease electric motor—Lub. No. 5	8250	A	1 hr.
2. Check oil level—Lub. No. 9	8251	W	5 m.
3. Drain compressor and receiver	8252	W	5 m.
4. Check V-belt tension	8253	W	5 m.
5. Check compressor's electric controls	8254	W	5 m.
6. Check operation of pressure gage	8255	M	5 m.
7. Check operation of air solenoid valve	8256	M	10 m.
8. Check operation of all valves and valve packing	8257	M	15 m.
9. Change oil and refill—Lub. No. 9	8258	S	45 m.
10. Dismantle and clean air solenoid valve	8259	S	30 m.

FIGURE 6.—Typical preliminary work sheet for preparing equipment maintenance card.

ment unit found to be needing some type of care. Next, each unit was analyzed and a list made of the required maintenance work, how often it was needed, how it should be accomplished, and approximately how long it should take to complete. Figure 6 is a typical listing. Where possible, reference was made to the manufacturer's literature accompanying the equipment or structural unit regarding its maintenance, and in many cases more information was requested. It should be mentioned that the manufacturers were happy to cooperate with this request, being equally anxious to see their equipment properly maintained. When no positive information as to frequency and methods was available, the best possible assumptions were made, with the reservation that if time proved otherwise, the cards could be amended accordingly. Where lubrication was required, the type of lubricant was listed by code number and the information later transferred to the finished card.

With all the unit data carefully recorded, the next step was to select and assign the specific times for the actual maintenance work to be done. First, all the preventive maintenance tasks were grouped by frequency—that is, weekly, monthly, etc. Next, an hourly schedule was made out for the entire work week, with due consideration being given to the time required for routine daily chores, such as the grinding of screenings, washing down, etc.; whether the work required daylight; and the location of the work. The various jobs were equally spread between shifts and days, using the estimated completion times as a guide. Mondays and Wednesdays were left as free as possible, on the assumption that Mondays would receive the burden of any trouble befalling the plant on weekends, and Wednesdays should be left for major jobs because of the presence of an extra operator during the day shift. Both of these assumptions have proved valid. The weekly cleanup tasks were assigned to Saturday and Sunday to avoid disturbance of daily routine.

After the weekly work had been assigned, a similar sheet was laid out to assign all monthly jobs. For the quarterly, semi-annual, and annual work,

the free Wednesdays and Mondays were then divided up and assigned. Mondays were still favored, in that the routine checking and inspection was scheduled, rather than the more time-consuming cleaning, lubricating, and overhauling. At no time during this distribution of work was the lack of available time a major problem. In fact, it was amazing just how much free time was available once the system was in complete operation.

The purchase and printing of the cards was the easiest step of all. A box of 1,000 5- by 8-in. cards with $\frac{3}{32}$-in. holes punched around the periphery was obtained from a local office supply store at a cost of $22.40. A local printer printed 500 of them for $18.54. Actually, it would have proved more economical to have had the entire amount printed at once, for many of the second 500 are already in use.

With the work assigned, and the information available on each phase of actual maintenance work required, the last step was to put the complete system into operation. Once all the information had been transferred to a card, each card was individually cut out to meet its assigned day and shift, keeping separate cards both by equipment and structural units, and by the frequency of the required maintenance work. A sample card similar to the one shown in Figure 7 was placed on top of the main office desk, with adjoining instructions as to its operation and how the daily assigned cards were to be pulled (Figure 8). After only a week of "growing pains," use of the punch card system became a routine operation. It quickly became apparent, however, that if they were treated like work sheets the cards would soon be lost or mutilated, and two safeguards were adopted for their protection. First, a complete set of duplicate cards was made and filed at the main District Office, away from the plant. Secondly, each operator was instructed that the cards were not to leave the office.

As in the other systems described, the operator, upon completion of the assigned work, fills in the date, item of

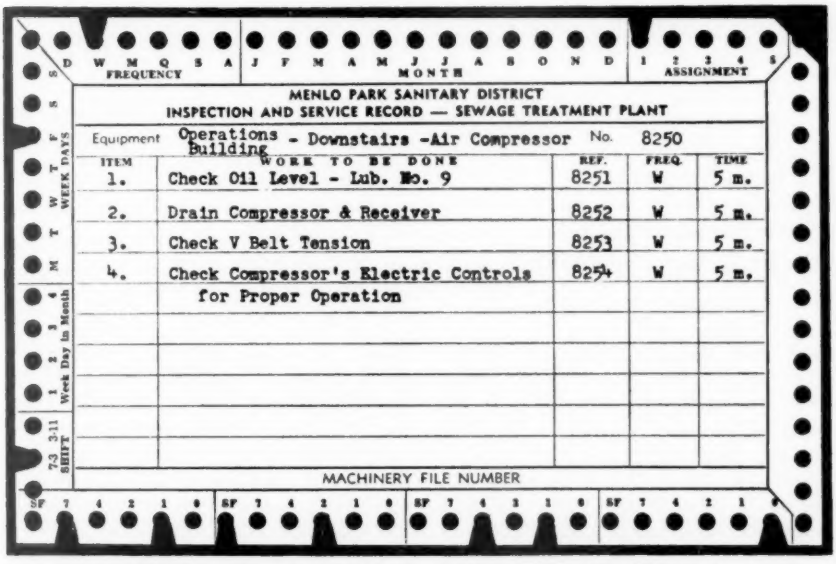

FREQUENCY
MONTH
ASSIGNMENT
MENLO PARK SANITARY DISTRICT
INSPECTION AND SERVICE RECORD — SEWAGE TREATMENT PLANT
Equipment Operations Building - Downstairs -Air Compressor No. 8250
ITEM
WORK TO BE DONE
REF.
FREQ.
TIME
1. Check Oil Level - Lub. No. 9 8251 W 5 m.
2. Drain Compressor & Receiver 8252 W 5 m.
3. Check V Belt Tension 8253 W 5 m.
4. Check Compressor's Electric Controls for Proper Operation 8254 W 5 m.
WEEK DAYS
Week Day in Month
SHIFT
MACHINERY FILE NUMBER

FIGURE 7.—Sample card for illustrative example (see Figure 8).

HOW TO FIND WORK ASSIGNMENT FOR THE DAY

(See Figure 7 for Sample Card)
Example Date: Friday, May 7, 1954;
7 AM–3 PM Shift; Operator on Duty

Step	Place Pick Through		Disposition of Cards That	
	Hole	Area	Remain on Pick	Fall Out
1	F	Week days	Return to File	To step 2[1]
2	W	Frequency	To step 3	To pile 1 (step 6)[2,6]
3	M	Frequency	To step 4	To pile 2 (step 5)[3]
4	M	Month	Return to file	To pile 2 (step 5)[4]
5	1	Week of month	Return to file	To pile 1 (step 6)[5,6]
6	7–3	Shift	Work on 3–11 shift	Work on 7–3 shift
7	1	Assignment[7]	Sort for further assignment	Work by operator

[1] These cards have work scheduled on Friday.
[2] These cards have work scheduled on Friday every week.
[3] These cards have work scheduled on Friday on monthly schedule.
[4] These cards have work scheduled on Friday during May.
[5] These cards have work scheduled on the first Friday in May.
[6] These cards have work scheduled on May 7, 1954.
[7] Assignment code:

1—Operator on duty.
2—Assistant or Chief Operator.
3—Electrician.
4—Special.
5—Extra help required.

HOW TO FIND CARD BY FILE NUMBER

Example Number: 8250 (see Figure 7)

Step	Place Pick Through		Disposition of Cards That	
	Number	Area	Remain on Pick	Fall Out
A	7	1	Return to file	To step B
B	1	1	Return to file	To step C
C	2	2	Return to file	To step D
D	SF[1]	2	Return to file	To step E
E	4	3	Return to file	To step F
F	1	3	Return to file	To step G
G	0	4	Return to file	8250 series

[1] Denotes "single figure."

FIGURE 8.—Instructions for finding daily work assignment and cards pertaining to any piece of equipment.

work done and his initials on the reverse side of the card. If something other than the normal routine is encountered, a note is made on the card and the card is placed on top of the office desk under "Items Needing Attention." If, for any reason, a card cannot be satisfactorily completed on the day it is scheduled, it also is placed on top of the office desk under the same file. In case of unexpected breakdowns or failures, reference to the back of the card or cards for that particular equipment or structural unit will bring the operator up to date on the care it has been receiving, and will possibly produce clues to the cause of the trouble.

One important difference will be noted in the Menlo Park card as com-

pared with the Santa Rosa card. Whereas at Santa Rosa only one card is used for each equipment or structural unit, at Menlo Park anywhere from one to five cards are used, depending on the different frequencies of the maintenance work required by that unit. When setting up the system we had no guide, and therefore felt that each card should be a unit in itself; that is, when a card was selected, all the work listed should be required to be done at that specific time. This, of course, required much more work in placing the data on extra cards, but that has been compensated for by the smoothness of the operation when once set up. Some needless back tracking has resulted, due to monthly or quarterly work overlapping weekly chores, but as this is noted the scheduling of the work is changed to avoid recurrence. The main advantage to our system is that each operator, with just a flick of an ice pick, may quickly and easily find the work assigned for his shift on any particular day, whereas with only one card per equipment or structural unit, the process is slowed up considerably.

The object of this paper has been to show the simplicity and ease with which the punch card preventive maintenance system can be set up and put into daily operation. The importance of preventive maintenance has long been established, but hitherto the dating, scheduling, and pertinent information has been elusive and unreliable, depending mainly on the memory of the operator and the accuracy of the filing system. The punch card system has eliminated all doubt, delay, and unnecessary burden from preventive maintenance, which has now become an easy, clear-cut, everyday routine.

IV. Application of a Modified System at a Small Plant

By Melvin J. Wise

Assistant Sanitary Engineer, Bureau of Sanitary Engineering, State Department of Public Health, Sacramento, Calif.

Built in 1943 for the Army as a general hospital and acquired by the state in 1946, the DeWitt State Hospital is now one of the major institutions operated by the California Department of Mental Hygiene. The average population is about 3,600, of which 3,000 are patients. At the hospital the card record system for preventive maintenance is used in modified form for the sewage system and also for the following additional facilities:

1. A water filtration and pumping plant.
2. A swimming pool employing recirculation of chemically treated and filtered water.
3. An oil-fired incinerator having provisions for can washing with hot water.

The raw surface water is derived from high Sierra sources and is treated by coagulation, filtration, and chlorination. Sewage also receives complete treatment in a biological high-rate filtration type plant. Plant effluent receives additional treatment through long detention by lagooning and chlorination.

The card record system was inaugurated at DeWitt in 1945, under the direction of Army engineers. Unfortunately, practically all of these records were transferred to Army headquarters when the hospital was deactivated in the spring of 1946.

When DeWitt was again activated (in late 1946, by the State of California), a new series of cards was set up. Because no printed forms were

available at the time, ordinary ruled 5- by 8-in. cards were used. However, the Army method of providing a card for each piece of equipment, valve, pump, etc., was not followed, nor was the edge-punch selection system, as described elsewhere in this symposium, employed. By consolidating and grouping the cards under alphabetic arrangements, the original number recommended by the Army was reduced by about 25 per cent. This resulted in a compact inventory of all of the more important pieces of equipment and other miscellaneous items, including storage reservoirs and tanks, upon which routine maintenance was performed.

The face of each card was devoted to such descriptive information and other important data as the following:

Line 1—Name and location of equipment or structure.

Line 2—Name of manufacturer, supplier, or builder.

Line 3—Approximate cost and date of installation.

Line 4—Type, style, etc.

Line 5—Capacity, size, rating, etc.

Line 6—Serial and code numbers.

Line 7—Nature and frequency of maintenance.

Line 8—Proper lubricants, paints, etc.

The backs of the cards were used in the same manner as the regular service records, as previously described.

This simplified system is adequate at small plants, particularly where all operation and maintenance is under the direction of one supervisor, and where record keeping is a task he himself must develop and perform. The degree of maintenance to be accomplished is naturally limited to the man-hours available and the funds allotted to the program. Moreover, the cards provide an easy reference when replacement parts are needed, but duplication of periodic service on certain items and use of improper lubricants is avoided. The card system also is extremely helpful in effectively "breaking in" new maintenance and operating personnel in a minimum of time, preventing abuse of equipment as well as sudden equipment failure, and providing an accurate repair and replacement record for budget purposes.

V. Application at the East Bay Plant

By Elmer E. Ross

Superintendent, Sewage Treatment Plant, Special District No. 1, East Bay Municipal Utility District, Oakland, Calif.

The necessity for and the application of the card record system in maintenance programs at small and medium sized plants have been described in the previous sections. This section describes how it has been applied at the East Bay sewage treatment plant, to illustrate its application at larger plants.

The East Bay plant was designed, constructed, and is operated by Special District No. 1 of the East Bay Municipal Utility District. It serves the cities of Alameda, Albany, Berkeley, Emeryville, Oakland, and Piedmont, and comprises approximately 21 mi. of intercepting sewers, 13 pumping stations, and a treatment plant designed to give primary treatment to an average dry-weather sewage flow of 128 m.g.d. and to handle a maximum intercepted rate of 291 m.g.d. The treatment provided consists of prechlorination, coarse screening, grit removal, sedimentation, and sludge digestion. Digested sludge is discharged with the

plant effluent into the deep waters of San Francisco Bay through an outfall sewer approximately 3 mi. long, the last mile of which lies on the floor of the bay.

The two largest pumping stations are located at the treatment plant, one to lift the sewage from the interceptor system to the treatment process, and the other to pump the plant effluent through the outfall sewer when, due to high rates of flow and high tides, its gravity flow capacity is exceeded.

A total of 41 employees is necessary to operate and maintain the treatment plant, pumping stations, and interceptor system. These are organized in two operating sections and a maintenance section, each supervised by a foreman. One of the operating sections operates the 11 lift stations on the interceptor system, the influent and effluent pumping stations, and the pretreatment works at the treatment plant. The other operates the sedimentation and digestion systems and the sanitary landfill used for screenings and grit disposal. The personnel assigned to each of these operating sections are divided into shifts, which are rotated every 12 weeks. The maintenance section is composed of a repairman, an electrician, and a crew of helpers. This section is responsible for the overhaul and repair of plant equipment, the maintenance of grounds and structures, and preventive maintenance that is beyond the capabilities of the operating sections.

The size of the staff, the periodic rotation of operating shifts, and the quantity and variety of equipment at larger plants, such as this, make a system for scheduling and controlling maintenance particularly essential.

At the time the present maintenance program was instituted, several systems then in use were considered, including one recommended by a leading equipment manufacturer, another by a firm specializing in setting up record control systems, and the system developed and used by the Army. A modified version of this latter system was finally adopted, because it was considered to be the simplest and most workable of those considered. As previously described, it consists basically of a record card containing space for listing and reporting the required inspection and service for each piece of equipment, and a manual containing the necessary instructions for performing the work.

The method of application differs somewhat from that described in the previous sections, however, because of the necessity for decentralizing operations and of having a separate maintenance section.

Record Card

The maintenance record card used is a modified form of the card used by the Army. A single card is made out for each piece of equipment required to be serviced, such as pumping unit, motor generator set, compressor, etc. On the upper part of the face of the card are entered all of the name-plate data for the unit and the shift to which it is assigned for maintenance. The remainder of this side of the card lists the work that is to be performed, the location in the maintenance manual that contains the instructions for doing the work, the frequency, and the day of the week or the month when the service is due. The reverse side of the card is used to record the work done and the date and initials of the person doing it.

Edge-punched cards are not used at the East Bay plant. Instead, the cards for all equipment assigned to a shift for maintenance are filed in three-ring loose-leaf binders in the order of descending frequency, beginning with those requiring daily or weekly entries. A card containing several frequencies is filed in the section corresponding to the highest frequency.

Thus, a card containing daily, quarterly, and annual entries is filed in the daily section, etc. Cards containing entries other than daily or weekly are flagged with metal tabs positioned to indicate the month the service is to be performed. When the entry is completed, the tab is shifted to the next month during which service is required.

Maintenance Manual

A maintenance manual containing complete instructions for servicing all assigned equipment is kept by each of the operating sections for use with the card files. The first part of each section's manual is the same and describes the methods and procedures to be followed in performing standard maintenance services, such as routine inspection and lubrication. The instructions therein pertain to servicing a class of equipment (for example, electric motors) rather than any specific unit. Its principal value in addition to standardizing methods is to assist in training new personnel, it being rarely used by the older employees.

The remainder of the manual is different in each section. Here are assembled and indexed the detailed operating and maintenance instructions and parts lists regularly furnished by the manufacturer for each piece of equipment assigned to the particular section.

These manuals contain all available information on the plant equipment and are always available to both operating and maintenance personnel. Thus, they not only serve as reference material for the maintenance record cards, but also are used by maintenance personnel when trouble shooting and when ordering parts.

Scheduling and Assignment of Work

Scheduling and assignment of work is done by the foreman of each of the operating sections, who is charged with the responsibility of seeing that all equipment operated by his section is inspected and serviced at the specified intervals. These intervals were originally established after consulting the manufacturer and weighing the following factors:

1. The importance of the particular piece of equipment.
2. The type of service required.
3. The cost of replacement.
4. The number of hours of operation during the interval. These intervals are periodically reviewed in the light of past operating experience and adjusted accordingly.

In general, the routine service, lubrication, and inspection not requiring disassembly are performed by the operating personnel. The periodic inspections that involve disassembly of a unit or require special tools are performed by the maintenance section.

The maintenance work performed by the operating section is divided among the three daily shifts, each shift being responsible for servicing certain pieces of equipment.

The System in Operation

In operation, the system works as follows. The shift operator daily consults the binder containing all of the cards assigned to his shift and performs the required inspection and service. This usually involves no more than looking at the unit, listening to it operate, checking the bearing temperatures by placing his hand on the housings, and making the entry on the card. This usually takes about 1 hr. He then consults the section containing the cards listing work to be done at less frequent intervals and performs as much of this work as the operating routine will permit on that particular day.

Inspection and service by the maintenance section is performed upon receipt of a work order initiated by the operator having custody of the card for that piece of equipment and ap-

proved by the section head and plant superintendent. When the maintenance section has completed the work, the work order is returned to the operating section, where the proper entry is made on the card. The work order is then destroyed. In this way, paper work is kept to a minimum and the need for a duplicate file of cards is eliminated.

The card files for each shift are inspected by the section foreman monthly. In addition, they are inspected two weeks before each shift change to see that the work is being performed as scheduled and the work load is properly distributed.

Summary

This system has proven to be simple and easy to use, and has thus far prevented equipment neglect. It has been of invaluable assistance in keeping the plant in efficient operating condition and controlling repair costs; trouble is often detected and corrected before expensive major breakdowns occur. The data recorded on the cards also furnish an operating history which is useful in substantiating the need for redesign or replacement of inefficient or unsuitable equipment and in stocking repair parts.

During the 2½ years the system has been in operation its use has been extended to include the servicing and inspection of such items as fire extinguishers, switchboards, power lawn mowers and other portable equipment, tide gates, and sewage diversion and overflow structures on the interceptor system.

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THE DAILY LOG

New Britain, Conn.

BY JOHN R. SZYMANSKI, *Superintendent*

July 2—A very important meeting of the Commission was held today. Because the problem of improving our receiving stream demands action, a suggestion and proposal to construct an 8-mi. conduit for the purpose of conveying our effluent directly to the Connecticut River is being considered seriously.

July 14—Received a request from a St. Louis physician inquiring about the effects the local water fluoridation program has on our sewage treatment process. To date no apparent effects have been noticed.

July 15—The long-awaited 500-c.f.m. air blower replacement arrived this morning. The old blower had just run itself out and was beyond economical repairs.

July 16—Notwithstanding safety checks by the Labor Department's representatives and our plant personnel, a tragic accident almost occurred

when the brake on the freight elevator just didn't hold. It seems some moisture got into the wrong place.

August 12—Excitement aplenty today. A body was found on property adjoining the plant site. It seems that some bandits robbed and shot an innocent Displaced Person and dumped the body during the early hours of last night. This happens to be murder No. 3 within the past five years.

August 14—Summer schedules are hindering our established paint and maintenance program. Usually, when the 48-hr. work week was in effect, even though vacations were being enjoyed by some employees, a good deal of outside work was completed; however, with the 40-hr. week and extended holidays, it is becoming difficult to plan any extra summer work. The Commission sat in session today with a special aldermanic group regarding the proposed conduit to the Connecticut River. No definite action resulted.

September 8—The new blower was placed in operation and immediate improvements in aeration were noted.

September 10—As a result of the semi-annual inspection of our boiler and heating system, the insurance company warns that replacement of the boiler may be necessary in the near future.

September 22—Great day! The City Hall really went up in flames during the evening, with extensive damage done to the offices of most municipal departments.

October 2—This was the day of the quarterly plant inspection by the Commission. Just as in the Army when top brass arrives, everything was spick and span and drew praise for plant personnel.

October 9—Contacts made regarding replacement parts for the remaining old blower proved useless. It seems that another company bought out the original manufacturer, but never fabricated any replacement parts—hence, no luck, no parts, and no replacements.

October 10—Received an odd inquiry from an industrial plant below our plant asking if we had changed our method of treatment. Upon investigation it turned out that layers of froth were appearing in the effluent receiving stream and accumulating at the dam near the downstream plant. No harm done; however, a further study of this condition is to be made.

October 14—Hard at work justifying our request for a higher compensation bracket for all of the sewage plant employees. The Civil Service Commission has promised a further review on this matter (see THIS JOURNAL, **25**, 2, 226; Feb., 1953).

October 21—After years of search for an odor-killer to combat the odors of raw sludge, we believe we have found something that is good, Cifon N.Y.—it isn't very expensive, either. More on this in a later "Log."

October 31—Usual fall operations. Nothing demanding extra attention; therefore, your "Logger" found time to complete the vacuum filtration questionnaire received a few days ago. These requests seem at first to have only nuisance value, but they can be used to good advantage by the person filling them out. In the first place, they make him review and assess his own operation; and the composite of experience from several plants may lead to improvements impossible of development from one plant alone.

November 13—The Sewage Disposal Commission met with the special aldermanic committee regarding plant and stream improvements. No definite action was taken, although further study was indicated.

November 20—All incinerator heat- and pressure-recording instruments were given their usual semi-annual check and servicing by a company representative.

December 5—The years roll fast; the day was spent in setting up the budget estimates for the next fiscal year.

December 17—The waste heat boiler developed some leaks. After necessary repairs were made it was decided to

gather information on its replacement. Accordingly, various heat equipment manufacturers were contacted.

December 25—Merry Xmas! The plant is being serviced by skeleton crews on an idling basis—the show must go on.

January 1—Happy New Year! These holidays are welcomed, but they place too much of a strain on equipment. This is especially true of the primary tanks, where we must store our sludge while the plant is on an idling basis.

January 6—More excitement! The Berlin, Conn., bank was held up at high noon today, with about $25,000 being taken by a lone bandit. The area surrounding the plant is alive with investigating police, both local and state.

January 14—A public hearing regarding a new outfall discharge into the Connecticut River was held by the State Water Commission at the State Office Building. No objectors were there, hence the city of New Britain may proceed with plans to direct its effluent into the Connecticut River at a point in Cromwell.

January 22—The State Police spent some time at the plant making inquiries concerning the recent bank hold-up in Berlin—just looking for information.

February 4—Because of the location of the new incinerator plant, to be built soon, it will be possible to provide heating facilities to eliminate the old waste heat boiler, and to connect the new incinerator stack to the multiple hearth furnace at the sewage plant. This latter arrangement will eliminate the existing stack and correct a smoke problem. The proximity of the new and existing facilities will make feasible a common parking area, thus conserving much-needed space.

The revolving safety committee, composed of the assistant superintendent and the day-shift operator, continued its diligent observations on safety matters pertaining to plant operations. The worth of this committee and the entire safety program is the best recommendation possible for adoption of such a scheme (see THIS JOURNAL, **25**, 7, 850; July, 1953) in other plants.

CAUSE AND CONTROL OF DETERGENT FROTHING —A REVIEW *

BY BENN MARTIN

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Causes of Frothing

Frothing on the aeration units at San Francisco's activated sludge plant in Golden Gate Park was a fairly common occurrence from the onset of operation in 1932, long before detergents were used to any appreciable extent. This frothing was concomitant with a low concentration of suspended solids in the mixed liquor, and could be and was controlled by increasing the concentration of those solids. Frothing always occurred when the plant was put into operation after a shutdown period. At such time as frothing did occur, it was at its height whenever the flow was interrupted or during periods of low flow. The frothing would begin midway between the inlet and outlet ends of the aeration tanks and build up toward both ends, but with a greater tendency toward the outlet end.

* Presented at 26th Annual Convention, California Sewage and Industrial Wastes Assn.; Sacramento, Calif.; May 5–8, 1954.

These and other observations are in substantial agreement with reports published in recent years. In 1941 in New York, under conditions which were apparently reproducible, frothing would occur when aeration tank solids were low for that plant. It has been noted that a transitory frothing phase occurred whenever mechanical aeration plants were put into operation; this frothing also was controlled as the solids concentration increased. Elsewhere a high dissolved oxygen content has been found coincident with frothing, and the appearance of the froth has seemed to follow a distinctive pattern (1)(2).

There is little doubt that what can be described as normal frothing, or frothing which occurred before detergents were in widespread use, occurred whenever mixed liquor solids were low or at some variance with the optimum for the plant.

It is probable that in any secondary treatment process there are always surface-active substances being produced as a result of biological degradation by enzymes or bacteria. These substances, when free and available in sufficient concentration, cause frothing. These higher levels of concentration of naturally occurring surfactants may be established when they are produced either at a more rapid rate than that at which they are being adsorbed, or when there is not sufficient surface area afforded by the solids present for their adsorption.

The amount of surfactant adsorbed by any surface is roughly proportional to the amount of surface, and although all water-insoluble substances will preferentially adsorb these surface-active molecules, the amount adsorbed will change depending on the amount of surface, its nature, the temperature, the surfactant concentration, and the pH of the solution (3). The free molecules which are unattached are able to migrate to the air-water interface, where they can operate in the formation of froth (4).

A re-examination of the conditions under which frothing occurred in the past will indicate that it could occur only if surface-active substances were being produced naturally.

Frothing at any given plant always occurred below a certain range of solids concentration, and only under unique conditions above that range. When frothing did occur, it appeared first at the effluent end of the aeration tanks. Since this was reproducible it can be assumed that at that point a sufficiently high concentration of free and available surface-active molecules had been reached; that is, under the particular set of conditions which existed apart from solids concentration, a maximum of adsorption had taken place and the excess was attracted to the air-water interface.

Since frothing occurred during an interruption in the flow, or during a low flow, it becomes reasonable to assume that either the rate of production increased or that again the maximum of adsorption had been reached so that, in any case, the excess affected the surface tension at the air-water interface.

Frothing has also occurred in the effluent miles removed from the plant and aeration tanks. The only possible explanation of these phenomena is in terms of such an hypothesis, which is predicated by the formation and existence of surface-active substances.

In 1953, for the first time, the production of synthetic detergents exceeded soap output in volume (5). The implications of this technological change may be summed up simply by stating that the most desirable factors in detergents may cause the most undesired effects in sewage treatment.

Most detergents are stable compounds and "their properties will persist long after the detergent solution is discarded under conditions of extreme dilution, changes in pH, oxida-

tion, and the digestion of microorganisms" (6). "It is thought that these surface-active agents do not form permanent chemical combinations in their applications, and that they are not generally destroyed in these applications" (7).

This paper proposes to show that the mechanism of surfactant behavior, as it applies to both the synthetic surface-active agent, and the substance produced as a result of biological degradation, can provide an explanation for the frothing which occurs under operating conditions that formerly seemed adequate for control.

Only on the face of it has a good case been made by Wells and Scherer (8) and by Gowdy (9) in establishing the fact that no direct relationship exists between frothing and the increased use of detergents. Gowdy (9) points out that the surface-active agents commonly used in detergents, when present in sufficient quantity, will froth immediately under the conditions of use.

This did not occur at either of two plants, where extensive and carefully controlled work was done with the addition of high concentrations of synthetic detergents at the influent end of the aeration tanks. It may be assumed, therefore, that the concentrations used were either not high enough, although they were three and four times that which might occur normally, or that, in fact, no direct relationship exists.

The preferential adsorption of these surface-active substances by solids (4) almost assures that no frothing is possible if sufficient solids are present, or until the maximum limits of adsorption by the surface area afforded by those solids is reached and exceeded. There doubtless exists for any sewage and at any plant some ratio of detergent concentration to surface area afforded by the solids in that sewage, at which frothing does not and cannot occur at the influent end of the aeration tanks.

That ratio, however, must change as the flow proceeds toward the effluent end, since the activated sludge process operates to remove solids from the liquid mass. Although the weight of the solids in the tank at any instant does not change appreciably, the surface area of those solids diminishes as a result of the adsorption and agglomeration which occurs when the return activated sludge is added to the incoming flow.

The mechanism of deterging or washing is nothing more than the formation of an emulsion. Such emulsions may be either stable or unstable. There would be no problem of frothing if the emulsions formed were all stable; neither might there be any treatment, because theoretically a stable emulsion would solubilize or suspend all substances not normally soluble in water.

It follows then, that whatever the conditions of use, enough of those emulsions formed are unstable and break down on dilution in the sewage. The rate of this breakdown and the desorption (10) which follows is increased under the conditions of the mechanical action of aeration, which at the same time is decreasing the surface area of the solids available for adsorption. The surfactant molecules which become free as a consequence may then be adsorbed at the air-water interface.

If this second hypothesis is correct, the frothing should become more evident as any increment approaches the effluent end. Moreover, unless there is some removal from the aeration tank solids of these surface-active substances, either in solution, which is possible in low concentration, or adsorption at the air-water interface, the maximum limits of adsorption by the surface area afforded by any concentration of solids, however high, would be reached as those solids were recycled. From that moment frothing would be continuous in that system.

There is evidence which indicates

that removal of surface-active substances from mixed liquor solids does take place. Keefer (11) shows this in data obtained at the Back River Works in Baltimore where the concentration of surface-active substances in the effluent from an activated sludge settling tank is higher than the concentration in the effluent from the activated sludge aeration tank.

Some relationship must exist, therefore, between the surface area of the solids present, the volume of the liquid mass, and the surfactant concentration, adsorbed, or free and available at the surface or in solution. It is this relationship that establishes the conditions for frothing in the system.

It would appear that secondary treatment processes utilizing aeration are adversely affected by surface-active substances which are (a) formed in the secondary treatment process as a result of biological degradation and (b) already present in the sewage and made free and available as a result of certain physical interactions which occur in the secondary treatment process. The cumulative effect of these components causes frothing under certain conditions of operation which formerly were adequate for control.

Control of Frothing

The control of frothing, wherever possible, is best achieved in terms of its causal factors. There is for any plant some level of concentration of mixed liquor solids or surface area afforded by those solids at which frothing will be controlled.

At Philadelphia's Northeast plant, 600 to 800 p.p.m. were sufficient to eliminate frothing (12). This was about the level maintained at the Bryan, Ohio, plant to control frothing there (9). Some frothing has occurred at the Nassau County (N. Y.) plant with 2,000 p.p.m. of solids in the mixed liquor (13). The plant at San Antonio, Tex., normally holds to a concentration of about 3,000 p.p.m., with froth appearing when the solids fall below 1,400 p.p.m. (8).

Enough data are available to prove quite conclusively that the mixed liquor solids concentration is critical in froth formation. This will bring no relief to those plants that must operate with low mixed liquor solids because of process modifications or by reason of aeration limitations (14). For some of these, another aspect of control by a causal factor may be possible.

The addition of settled sewage in increments along the course of flow through the aeration tanks has been found quite effective. Wherever the settled sewage is added, the froth disappears (1).

This technique maintains control by keeping the surface area of the solids at a sufficiently high level so that the preferential adsorption of the free and available surface-active molecules by these solids will lower the concentration at the air-water interface. At the Gruppen plant in Germany (15) instead of feeding the settled sewage at isolated points in the aeration tanks, V-notch weirs similar to those used in settling basins were installed. The sewage flows through the notches into the aerator along its entire length. This type of distribution has been found more effective than increment feeding, since the aeration tank is affected over its whole length, and the frothing is controlled over almost the entire area.

Defrothing

Wherever control in terms of the cause and effect relationship is not possible, the only recourse is to defrothing. The simplest defrothing is a mechanical breakdown by water spray, using plant effluent. This can be quite effective with an efficient spray pattern. At Los Angeles (16) a flat spray pattern covering 180° and impinging

on the water surface in the direction of roll, as close to the concrete face as possible, proved effective in the aeration tanks. The nozzles are mounted at 7-ft. centers and deliver 2.4 g.p.m. at 10 p.s.i. The froth builds differently in the effluent channel and a flat spray pattern covering 90° is used there.

For the whole system, with a total of 9,600 ft. of spray, 4,000 g.p.m. at about 15 p.s.i. are used. This is in agreement with Greeley (13) who indicates that 15 to 20 g.p.m. per m.g. of flow, or 0.25 to 0.50 g.p.m. per foot of aeration tank has been used for mechanical breakdown.

Chemical defrothing or anti-foaming agents are used to reduce, eliminate, or inhibit frothing when the use of water sprays alone is not sufficient to maintain control. These substances may be added either to the spray water, as is done at Los Angeles and the 26th Ward plant in New York City, or applied to the return sludge or multiple points on the aeration tanks, as is done at the other three New York City plants (17). At the Los Angeles Hyperion plant the defrothing agent is diluted with a suitable solvent and injected with a proportioning pump into the section of the spray system where and when it is needed.

The absence of any relationship between the surface tension of a chemical compound and its ability as a froth inhibitor has led Garber (16), at the Hyperion plant, to develop a testing technique for evaluating the effectiveness of these compounds; since the best defrothing agent may not be the one which is most effective at the lowest concentration. More than 50 such defoamants have been examined. Garber (16) also has found that an inhibitor successfully applied at one plant may fail at another.

During the worst frothing condition, about 0.6 lb. per m.g. of flow is used. This represents a chemical cost of $0.09 per m.g. Costs will doubtless vary from plant to plant. Estimates found in recent literature range from $0.50 to $1.00 per m.g. of sewage treated (18).

Although detergents may be formulated for use without frothing, the common household standard for good cleansing action is suds or froth. It is not likely, therefore, that the time is at hand when a non-frothing compound will be generally accepted (18).

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TIPS AND QUIPS

Scum Control on Open Digester

When the 15-in. thick dry scum on an open-cover digester became a choice breeding ground for flies, one enterprising operator broke up the scum with a portable pump and some 2-in. hose. Once the initial scum break-up proved effective, according to the August 1954 issue of *The Overflow*, it became impractical to continue the break-up by this means because the pump had to be hoisted by block and tackle 22 ft. to the control house roof. This difficulty was overcome, however, by breaking up the thinner scum periodically (about every three weeks) with a long-handled paddle.

Cork Insulation Tape

A new cork insulation tape said to be especially developed as an insulating material for cold lines and wherever the problem of condensation is encountered, also is claimed to be an effective sound deadening barrier and gasketing material. According to the manufacturer, Dennis Chemical Co., 2701 Papin St., St. Louis 3, Mo., the tape has excellent adhesion to itself and all types of surfaces.

First Oregon Short School

An attendance of 63 persons, representing 42 systems, got the Oregon Sewage Plant Operators Short School Program off to a good start when the First Annual Short School was held at Corvallis, Ore., on April 28–30, 1954. The program is jointly sponsored and conducted by Oregon State College and the Oregon State Board of Health.

"Trouble Savers"

Preventive maintenance and easy location of trouble are the subjects of a series of "Trouble Savers" now available from the Worthington Corp., Harrison, N. J. Graphically illustrated, the easily filed and readily readable bulletins currently available cover air-cooled and water-cooled air compressors (PC–306), pumps (PC–305), vertical water-cooled air compressors (L–676–MI), and V-belt drives (V–1400–M39).

Fly Control

Growing resistance of house flies, often nuisances around a sewage treatment plant, to DDT has resulted in development of a baiting method for getting flies to feed on insecticides containing Lindane. Diluted corn syrup is used as the bait, with the insecticide dissolved directly in the bait solution. Flies feeding on the poisoned bait die in 1 to 5 min., although maximum fly reduction is claimed to be noted 4 to 6 hr. after application.

Details of the baiting fly control method and dosages of insecticides to

use may be obtained from California Spray-Chemical Corp., Richmond, Calif.

Fish Suffocated by Lack of Oxygen

Suffocation apparently caused the death of thousands of fish found floating on the surface of Chesapeake Bay over the Labor Day weekend (September 4–6, 1954), according to marine experts. Engineers reported that an upwelling of water containing very little oxygen had caused the fish to suffocate. Recent hurricane winds were blamed for the upwelling.

The Case of the Loose Valve Shaft Coupling

When operation of the manual valve stand failed to open the sludge withdrawal line valve at the Plainville, Conn., sewage treatment plant, the operator faced an unpleasant job. Under the circumstances there was nothing to do but draw the tank down, make the repair, and get the tank back in operation as quickly as possible. That, however, did not eliminate the possibility of the same disruption occurring again. What had happened was that the pin in the shaft extension coupling had broken and the set screw had loosened—the coupling simply slid down on the stem as far as it could go.

To forestall a reoccurrence, Operator Theodore E. Fanion not only restored the coupling, with a new shear pin and set screw, but also installed a collar with two set screws (Figure 1) to prevent the coupling from sliding down on the shaft. He also suggests that the coupling could be prevented from slipping down by putting a piece of pipe of the correct length over the valve stem as a spacer.

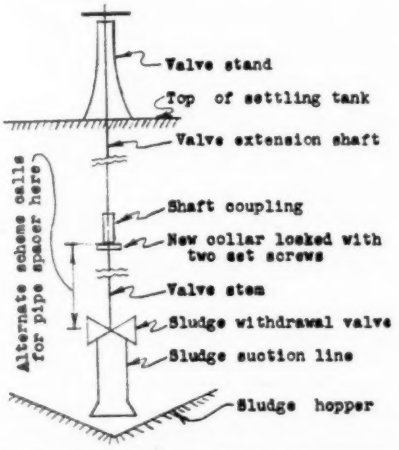

FIGURE 1.—Two methods of preventing "loss" of loose valve stem coupling.

Information Needed About Municipal Sewer Ordinances

The Federation's Manual of Practice No. 3 on "Municipal Sewer Ordinances" seems to be an exceptionally popular publication with those involved in drawing up and administering such regulations. This is attested to by the fact that nearly 8,000 copies have been distributed, which is barely exceeded by only one other manual. Of this number, 2,700 copies have been sold, many to city managers, city attorneys, city engineers, and other high-ranking municipal officials.

Despite the knowledge that the manual is going to people having great interest in its content and recommendations, there is no direct way of knowing to what extent the manual has been used in drawing up or revising new or existing sewer ordinances.

Managers, superintendents, and operators can help in finding out, however, if they will drop a post card to "The Corner" wherever it is known that Manual No. 3 was used either directly or indirectly in developing or revising the sewer ordinance presently in force. Such post cards should be addressed to: The Operator's Corner, *Sewage and Industrial Wastes,* 325 Illinois Building, Champaign, Ill., and give a brief statement of any positive knowledge of use of the manual.

Reviews and Abstracts*

Experiments on the Microbiology of Cellulose Decomposition in a Municipal Sewage Plant. By Leroy R. Maki. *Antonie Van Leeuwenhoek*, **20**, 185 (1954).

The study concerns itself with the anaerobic decomposition of cellulose. It was found that of the total organic matter in raw sludge obtained from a domestic sewage, nearly one-half was cellulose. Cellulolytic bacteria in sludge from a primary digester counted by special culture medium ranged from 16,000 to 970,000 per ml. Ten strains of cellulolytic bacteria were isolated. The organisms could be separated into two groups with active and less active cellulolytic powers. The products of decomposition of cellulose by these organisms were hydrogen, carbon dioxide, ethanol, formic, acetic, and lactic acids. By adding to the medium more cellulose than could be fermented, it was possible to demonstrate the production of glucose as an intermediate product by the paper chromatographic method. A pure culture of the active cellulose-decomposing organism gave a rate of disappearance of cellulose of 0.026 per cent per day. The addition of a non-cellulolytic bacterium also isolated from sludge to active pure culture increased the rate of cellulose disappearance to 0.066 per cent per day. The rate of fermentation of cellulose by pure culture was not affected by the addition of acetate up to 5,000 p.p.m.

H. Heukelekian

Study of Trickling Filter Fungi. By C. W. Hasseltine. *Bull. of the Torrey Botanical Club*, **80**, 6, 507 (Nov., 1953).

A study of the fungi occurring in trickling filters receiving antibiotic wastes from the Lederle plant was made over a year. Samples of stone from three different positions in the bed were taken once a month and examined microscopically. Fungi were found to be a regular portion of the flora. Only three species of fungi were found regularly in large quantities, as follows: (a) *Fusarium episphaeria*, forming yellow-orange moist masses, imparting at times a dull reddish color to the stones, occurs in largest amounts in spring, summer, and fall; (b) *Oospora lactis*, which is more abundant in winter months, appears as grayish mucus-like masses and is found both at the surface and some distance below in the bed; and (c) *Subbaromyces splendens*, not found on the surface of the stones but occurring abundantly on the underside of the surface stones as well as deep down in the bed, occurs as blackish masses. A detailed description of this organism is given and it is claimed to be a new genus.

H. Heukelekian

Further Investigations of Concentration of Raw Sludge. By J. F. Laboon. *Proc. Amer. Soc. Civil Eng.*, **79**, Separate No. 314 (Oct., 1953).

Further operation of a pilot plant for concentration of raw sludge by flotation has shown improved results and has made it possible to try several methods of sludge handling. Return of subnatant liquor from the concentrator to the pre-aeration tank stimulates the production of gas and produces a sludge of increased total solids content. Pre-chlorination seemed to result in a sludge slightly less dense.

Laboratory filtration tests have shown that sludge concentrated without chemicals for 48 hr. can be handled by conventional methods and can be filtered on a filter leaf without the need for dilution, which was found necessary when filtering 120-hr. concentrated sludge.

Gravity drainage of sludge following the subnatant removal greatly increased the total solids concentration, but a more practical method of doing this must be developed. The beneficial effects obtained

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in This Journal. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage and Industrial Wastes Assns., 325 Illinois Bldg., Champaign, Ill.

by increasing sludge temperatures were further proven.

Several tables and graphs of data are included. W. A. HASFURTHER

Sewage Aeration Practice in New York City. BY R. H. GOULD. *Proc. Amer. Soc. Civil Eng.*, **79**, Separate No. 307 (Oct., 1953).

The three modifications of aeration that are used are described and operation results are tabulated. In step aeration by distributing fresh feed throughout the tanks it is felt that air requirements are more uniformly spread and better air economy is obtained. The final tanks are designed and operated so that the activated sludge is settled and returned to the aerator in 30 min. Sludge age is usually kept at about 3.5 days.

The "modified aeration" or "high-rate activated sludge" process provides an intermediate treatment. The pattern is like the conventional process, but the air use is cut to about 0.4 cu. ft. per gallon, the aeration period is reduced, and the sludge age is kept at 0.2 to 0.5 days. A dense final tank sludge is obtained.

The "activated aeration" process was devised for use in parallel with step aeration. Waste from the "step" battery is introduced into the head of another battery and aerated there with sewage. Sludge from this battery and excess from the other is removed. The tabulated results showed a better reduction than was obtained through the modified method.

Comparative results for the step, modified, and activated methods were, respectively: air used, 0.49 to 1.05, 0.33 to 0.55, and 0.19 cu. ft. per gallon; aeration period, 2.4 to 4.7, 1.6 to 2.8, and 2.8 hr.; B.O.D. reduction, 87 to 95, 44 to 72, and 76 per cent. W. A. HASFURTHER

Performance of Biofiltration Plants by Three Methods. BY R. S. RANKIN. *Proc. Amer. Soc. Civil Eng.*, **79**, Separate No. 336 (Nov., 1953).

The author, using limitations prescribed by the "Tentative Standards 1951," issued by the Upper Mississippi River and Great Lakes Boards of Public Health Engineers, for filters with recirculation, developed formulas for single- and two-stage units. He compares efficiencies computed by these formulas and those of the National Research Council and Velz with actual data from several operating plants.

For single-stage units the Velz formula gave results closest to the actual, but because it also gave close results and was easier to apply, the "Tentative Standards" method was considered preferable. The Velz method does not apply to two-stage filters, and checks by the other methods again show the "Tentative Standards" method to be preferable.

There is also discussed an intermediate type of treatment using primary clarification with filter effluent recirculated to the primary tank inlet. Part of the settled effluent is then withdrawn as final effluent. This effluent can also be put onto another filter followed by a final clarifier. Operating data are given for two plants of this latter type. W. A. HASFURTHER

Industrial Waste Process Design. BY W. W. ECKENFELDER, JR., AND D. J. O'CONNOR. *Proc. Amer. Soc. Civil Eng.*, **80**, Separate No. 411 (Feb., 1954).

This paper contains a brief review of what information should be otained in an industrial waste survey and a discussion of the theoretical and practical application of such information. The use of data in design is illustrated by flow sheets, graphs, and tables.

In sedimentation the size of the particle and viscosity are important and the authors suggest a laboratory test to provide basic design data. They give examples covering investigation and design for settling tanks for two types of wastes.

Design of biological systems is complex because of variances in the type of matter, rates of transformation, oxygen and nitrogen utilization, and quantity of sludge produced. The aerobic biological process and reaction covering auto-oxidation of sludge can be described by two equations:

$$\text{Organic matter} + O_2 + NH_3 = \text{Sludge} + CO_2 + H_2O$$

and

$$\text{Sludge} + O_2 = CO_2 + H_2O + NH_3$$

Generally the factors necessary to balance these equations must be determined by laboratory or pilot-plant studies. How this can be done is explained in some detail and includes the use of graphs and curves that enable the designer to use the experi-

mental data for different conditions of loading or waste concentration. The discussion covers activated sludge plant design, but the principles are said to be equally applicable to the design of trickling filters. A bibliography of references on this subject is included.

W. A. HASFURTHER

Hyperion—The Los Angeles Sewage Treatment Plant. BY F. L. FLOOD. *Jour. Boston Soc. Civil Eng.*, **41**, 164 (1954).

The author sketches briefly the history of the pollution of Santa Monica Bay by Los Angeles at Hyperion, which resulted in a report by Metcalf & Eddy in 1944 and the construction of the Hyperion plant, which is designed to handle a flow of 245 m.g.d. with a daily peak flow of 350 m.g.d. and storm flows up to 420 m.g.d. At present (1954) the flow treated averages 230 m.g.d. The plant comprises coarse bar screens (1-in. openings), disintegrators, detritors (3 at 60 ft. square, 5 ft. deep), covered pre-aeration units (30-min. period), and eight covered primary settling tanks (1½-hr. period).

Settled sewage is treated by high-rate aeration (3.3-hr. period, with small amount of return sludge) in 16 tank units, each with two channels 30.5 ft. wide by 300 ft. long, with 15-ft. water depth. Normal air supply is 0.7 cu. ft. per gal. of sewage, Mixed liquor is settled in 20 settling tanks. each 125 ft. long, 76 ft. wide, average water depth of 15 ft., detention period 2 hr., surface loading 1,290 g.p.d. per square foot, and weir overflow of 10,410 g.p.d. per linear foot. Chlorine is applied to the raw sewage as it enters the rack building, to the settled sewage, and to the plant effluent discharge. Six chlorinators, each of 6,000-lb.-per-day capacity, give a total capacity of 36,000 lb. per day.

The plant outfall consists of 12-ft. pipes, with dispersal at multiple outlets in 50-ft. depth about 1 mi. from shore.

Excess activated sludge is returned to the sewage ahead of the pre-aeration tanks and is settled out with the primary sludge for pumping to 12 heated sludge digestion tanks (18 units, each 111 ft. diameter and sidewall depth of 30.5 ft.). Total digestion capacity is about 6,000,000 cu. ft. (about 2 cu. ft. per capita.)

Digested sludge is elutriated,conditioned with ferric chloride, and dewatered on 12 vacuum filters before being further dewatered in four flash dryers. Normally, sludge is dried for use as fertilizer, but it can be incinerated. Water vapor, furnace gases, and foul air are vented through a stack 200 ft. high. Fuel for drying is normally digester gas, but natural gas or oil can be used. Heat-dried sludge is pelletized (moisture 8.6 per cent) for fertilizer, with an annual production of 22,000 tons dry basis.

Gas from digestion exceeds 5,000,000 cu. ft. per day and is used in power generation and air compression (7¾ lb.) in nine 1,688-hp. dual-fuel supercharged engines.

In the bathing season of 1953, treatment removed about 80 per cent of suspended solids and 5-day B.O.D. and the chlorine demand was reduced from 22 p.p.m. to 3.5 p.p.m.

Preliminary estimates on operating costs show that the unit cost of $17.17 per m.g. at an average flow of 245 m.g.d. can be reduced to $14.06 per m.g. at 300 m.g.d.

LANGDON PEARSE

Recent Advances in Sewage Treatment in New York City. BY RICHARD H. GOULD. *Jour. Boston Soc. Civil Eng.*, **41**, 2, 208 (1954).

The various process improvements made during the period 1948–54 at the several sewage treatment plants of New York City are described and discussed. Among the more important are "activated aeration" (see THIS JOURNAL, **26**, 9, 1059; Sept., 1954), sludge concentration, and high-rate sludge digestion (see THIS JOURNAL, **26**, 4, 479; Apr., 1954).

H. P. O.

Subdivision and Fringe Area Control. BY DENNIS O'HARROW. *Amer. Jour. Pub. Health*, **44**, 473 (1954).

Because a very sizeable portion of the American population lives in urban fringe areas, the problem of control of these areas, is a real and timely one, particularly from the standpoint of health and safety. Poor planning, layout, utility service, transportation facilities, and shopping facilities are all partially to blame. Subdivision ills are classified as due to prematurity, poor design, or incompleteness. Bad design is censured as a more serious fault than premature subdivision. H. P. O.

Operating Problems at Hyperion Treatment Plant. By C. N. Sawyer. *Jour. Boston Soc. Civil Eng.*, **41**, 178 (1954).

The sewage is about 18 hr. in transit, with temperatures ranging from 68° to 83° F. On arrival at the plant, it is deficient in oxygen and abundant in H_2S. The pre-aeration units arrest further development of H_2S.

The treatment applied is low in concentration of aeration solids (normally 200 to 300 p.p.m.), with about 140 p.p.m. contributed by settled sewage. Air requirements aggravate the frothing and a modification of aeration devices is suggested. Final settling tanks accumulate considerable amounts of grease and scum.

Return sludge facilities are too large and pumps require severe throttling. Also, the holding time in the return sludge conduit is too great (30 to 60 min.) and return sludge aeration channels are to be eliminated, because of degradation of sludge. Sludge wasting facilities appear very delicate for satisfactory operation.

In the digestion units, the effect of the different temperatures on the filtering properties of the sludge is being studied.

The activated sludge treatment markedly reduces the chlorine demand, with an estimated saving of 18 tons of chlorine per day and an annual saving of about 3,000 tons, or about $300,000.

Shortcomings of the present plant are thought to be possible of rectification at a nominal cost. Langdon Pearse

Metropolitan Water, Sewerage and Drainage Board, Sydney, N.S.W., Australia. 65th Ann. Rep. for Year Ended June 30, 1953. 49 pp. (1954).

This is a very complete report, with financial data and maps, of a Board serving Sydney and suburban areas. On June 30, 1953, 2,032,000 persons received water service, 1,427,000 sewerage, and 886,500 drainage. Most of the population is located in an area of 526 sq. mi.

Sydney and its suburbs are served by three major sewerage systems, which discharge without treatment to the Pacific Ocean in 30 ft. of water. Of the five minor sewer systems, three discharge into the ocean and two drain to local treatment works.

As surf bathing has developed since the ocean outfalls were constructed, steps are now being taken to eliminate any possibility of nuisance on neighboring beaches. At the Bondi outfall these comprise screening and grease removal, with the final result of screening and sedimentation of the dry-weather and storm flows.

Rehabilitation work is under way at certain minor sewage treatment works to better the protection of bathing beaches.

In 1953 the total expenditures for all construction purposes was £5,385,489. The total revenue was £6,672,577, of which 61.8 per cent was from water rates and fees, and 36.4 per cent from sewage rates.

The expenditures from revenue were £6,667,529, of which capital debt charges amounted to 48 per cent, management 13.1 per cent, general maintenance 18 per cent, and pumping 13.6 per cent.

Research is being continued on the deodorization of sewer gas by ozone.

Langdon Pearse

1952 Annual Report, Bureau of Sewers, Worcester, Mass.

This annual report covers the activities of the Bureau of Sewers, including construction and maintenance of sewers, cleaning of catch basins, and operation of the sewage treatment plant.

The treatment plant operation proceeded normally throughout the year. Continued cooperation of industry relative to removal of acid iron wastes from the sewer system showed in the maintenance of a 6.8 pH average. The removal amounted to 860,000 gal. per year. The final results in B.O.D. and suspended solid removal were approximately the same as in 1951 (81 per cent and 89 per cent). This can be increased by better removal of grit and rags, thus alleviating operating difficulties with the Imhoff tanks.

The average daily flow was 27.04 m.g.d. Grit and screenings removed averaged 3.41 cu. ft. per m.g. sewage. The Imhoff tanks removed 3,211.26 tons of dry sludge. The trickling filters were dosed in part at 2.90 and 2.78 m.g.a.d.

The final effluent showed an average yearly over-all B.O.D. reduction of 83.3 per cent and 81.1 per cent through different parts of the plant.

The Imhoff sludge was pumped to the drying beds, which were cleaned by contract at $1.44 per cu. yd.

The quality of the Blackstone River was satisfactory, with a relative stability of 99 per cent and dissolved oxygen at 75 per cent saturation. LANGDON PEARSE

Algae Research on Oxidation Ponds. By CHARLES E. RENN. *Amer. Jour. Pub. Health*, **44,** 631 (1954).

Domestic sewage from a community of 10,000 might be made to produce almost 1,400 lb. of protein each day if the treatment process described were employed. Although the process is suited chiefly to dry bright climates, interest in it will be general.

The chief advantage, from the sanitary engineer's viewpoint, is the control that is possible over the process. Actually the process utilizes sewage oxidation ponds for growing selected algae, which are then used for cattle feed. One problem to be overcome is the dewatering of the algal growth and the high B.O.D. of the water suspension when discharged to natural streams. H. P. O.

Development of Sanitary Districts for Water, Sewage, Drainage, and Refuse Control. By MORTON S. HILBERT. *Amer. Jour. Pub. Health*, **44,** 467 (1954).

Experience gained in meeting some of the emergent sanitary problems created in the environs of Detroit, Mich., by the rapid expansion of suburban fringe areas is reviewed with a view to helping in the solution of similar hazards to health and safety. Among the major points stressed by the author are the absolute necessity for inter-agency cooperative planning and policy determination, planning for the most economical and impartial protection on an area-wide basis, and organization of an improvement program that is more than remedial and will consider the long-range needs of the community.

H. P. O.

Treatment of Chemical Wastes. By I. S. WILSON. *Surveyor*, **113,** 315 and 339 (1954).

Monsanto's plant at Ruabon (England) produces fine organic chemicals. Due to expansion of the production facilities, the practice of underground disposal of strong liquors and controlled discharge of weak wastes became insufficient to protect the receiving stream. Laboratory-scale trickling filters gave 92 per cent phenol removal from the combined wastes, but a 6-ft. pilot unit gave only 40 to 45 per cent removal. The full-scale plant consists of six trickling filters in parallel, with accessory tanks and equipment for equalization and neutralization of the raw waste, sedimentation before and after the filters, and recirculation of treated effluent. Sludge is conditioned with ferric chloride and lime and dewatered on sand beds.

Pilot-plant studies of activated sludge employed both diffused air and mechanical aeration units, and dealt with treatment of both the raw wastes and the trickling filter effluent. In the diffused air system, retention times varying from 11 to 24 hr. gave from 63 to 88 per cent phenol removal, while 9.5 to 21.5 hr. retention in the mechanical system gave removals of from 63 to 83 per cent.

Wastes from the production of phthalic anhydride, synthetic phenol, salicylic acid, and phenetidine showed no toxicity when isolated and studied on laboratory-scale trickling filters. Toxicity was demonstrated with sodium sulfate, acetic acid, and the mixed wastes from production of chemicals for use in rubber processing.

M. C. RAND

BOOKS, REPORTS, AND PAMPHLETS

Digest of Sewerage Enabling Acts of California. Publ. No. 1, State Water Poll. Control Board, Sacramento, Calif. 64 pp. (Revised 1954).

An up-to-date revision of a 1951 compendium, including a condensed table comparing types of sewerage district, procedural steps in formation and financing of five types of district, and a statewide listing of six types of district now providing sewerage services.

Instrumentation in Water, Sewage, and Waste Treatment. Instruments Publ. Co., 845 Ridge Ave., Pittsburgh 12, Pa. 48 pp. Price, $2.00 (1954).

Contains the proceedings of the 1953 Conference on Instrumentation in Water, Sewage, and Industrial Waste Treatment, held at Manhattan College (N. Y.) May 14, 1953.

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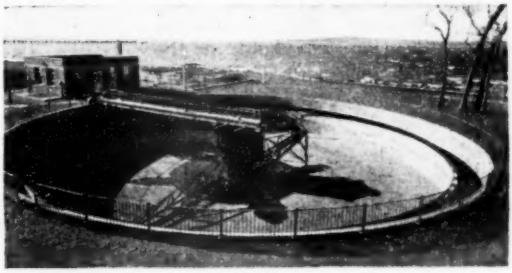

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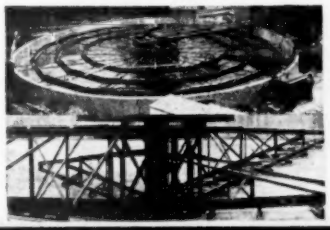

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Proceedings of Member Associations

CALIFORNIA SEWAGE AND INDUSTRIAL WASTES ASSOCIATION

The 26th Annual Convention of the California Sewage and Industrial Wastes Association was held at the Hotel Senator, Sacramento, Calif., May 5–8, 1954. The registration of 306 men and 92 ladies was only two short of the attendance record set in 1953.

The following papers were presented:

"Biocatalytic Additives in Waste Treatment," by Jack E. McKee, Associate Professor of Sanitary Engineering, California Institute of Technology.

"Disposal of Digested Sludge by Dilution," by A. M. Rawn, Chief Engineer and General Manager, and F. R. Bowerman, Division Engineer, Los Angeles County Sanitation Districts.

"Detergent Frothing: Cause and Control," by Benn Martin, Superintendent of Richmond-Sunset Sewage Treatment Plant, City and County of San Francisco.

"The Application of a Simplified Technic to Atmospheric H_2S Studies," by Gerson Chanin, Chief Sanitary Chemist; John R. Elwood, Junior Sanitary Chemist; and Edward H. Chow, Senior Sanitary Chemist, East Bay Municipal Utility District, Oakland.

"Features and Financing of Sewerage System Serving the Sacramento Metropolitan Area," by Carl Jennings, Assistant City Engineer, Sacramento.

(*Continued on page 458a*)

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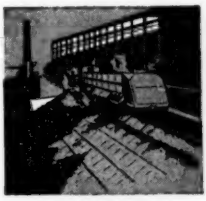
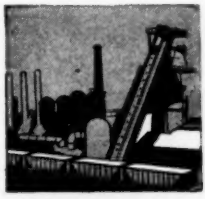
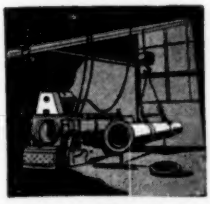


Coke Ovens



Blast Furnaces



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"Design and Construction of Sacramento's New Sewage Treatment Plant," by Richard R. Kennedy, Partner, Engineering Office of Clyde C Kennedy, San Francisco.

"Symposium on Record Systems for Preventive Maintenance," by a panel comprising J. T. Norgaard, Civil Engineer, Brown and Caldwell, San Francisco; M. J. Wise, Assistant Sanitary Engineer, State Dept. of Public Health, Sacramento; M. B. McKinnie, Superintendent of Sewage Treatment, Santa Rosa; W. R. Uhte, Chief Operator, Sewage Treatment Plant, Menlo Park; and E. E. Ross, Superintendent of Sewage Treatment, East Bay Municipal Utility District, Oakland.

"Safety in Plant Operation and Sewer Maintenance," by J. E. Gilmore, Director of Safety, Celite Division, Johns-Manville Products Corp., Lompac.

"Some Studies on the Operational Use of Sludge Digestion at Elevated Temperatures," by William F. Garber, Laboratory Director, Sewage Treatment Division, Bureau of Sanitation, Los Angeles.

"Anaerobic Digestion of Industrial Wastes," by Erman A. Pearson, Assistant Professor of Sanitary Engineering, University of California, Berkeley.

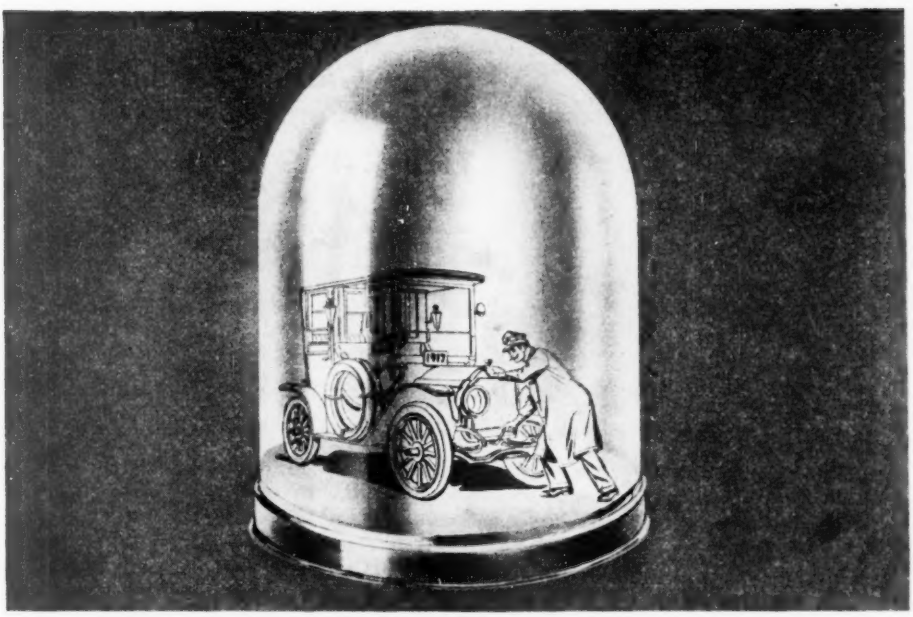
"Odor Control from Sewage Pump Stations," by Richard Pomeroy, Pomeroy & Associates, Pasadena.

"Management and Adjustment of pH of Industrial Wastes," by W. J. O'Connell, Jr., Industrial Consultant, Burlingame.

"Coordination Among Groups Interested in Industry Growth, and Location, Waste Disposal Systems, and Water Pollution Control," by D. V. Doub, Industrial Power Engineer, Pacific Gas and Electric Company, San Francisco.

"The City Looks at Requirements for Pre-Conditioning of Industrial Wastes," by Ross Miller, City Manager, Modesto.

(*Continued on page 460a*)



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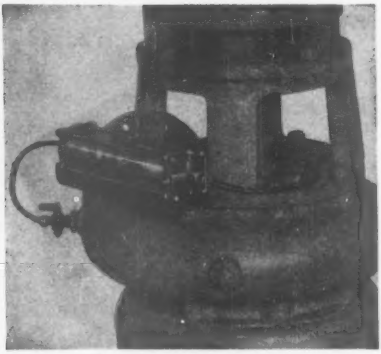

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"Radioactive Wastes in Sewage," by Albert W. Bellamy, Professor of Biophysics, University of California at Los Angeles, and Chief, Radiological Safety Services, State Office of Civilian Defense, Sacramento.

"Characteristics and Treatment of Sewage at State Institutions and Facilities," by Edwin R. Stowell, Senior Sanitary Engineer, State Division of Architecture, Sacramento.

"Observations of Sewage Treatment in England," by E. Sherman Chase, Partner, Metcalf & Eddy, Boston, Mass.

The Operators' Breakfast and the Sewer Maintenance Breakfast, held concurrently, were both well attended. At the Operators' Breakfast the following subjects were presented for discussion:

"Repair Shops in Treatment Plants," by Arthur Vieira, Superintendent, Sewage Treatment Plant, Manteca.

"Lubricating Greases," by H. J. Miller, Chief Operator, Sewage Treatment Plant, Marysville.

"Certification—Progress Report," by T. J. Mays, Superintendent, Sewage Treatment Plant, Santa Maria.

The Sewer Maintenance Breakfast presented the following subjects for discussion:

"Why Preventive Maintenance for Collecting Systems is Economically Justified," by Cedric Webster, Superintendent, Menlo Park Sanitary District.

"Maintenance of Special Structures," by Howard Kaulbach, Street Maintenance Engineer, Oakland.

"Determination of Pipe Conditions by Inspection or Use of Tools," by John A. McCollum, District Foreman, Sewer Maintenance Division, Los Angeles.

"Methods for Removal of Incrustation, Scale, Grease, and Industrial Waste Deposits from Pipes," by Bud Sketchley, Owner, Rodding-Cleaning Machines, Inc., Los Angeles.

During an inspection trip to the new Sacramento sewage treatment plant, under construction, Sydney Preen, Superintendent of Sewer Maintenance, Long Beach, demonstrated sewer cleaning techniques used in that city.

Arthur T. Wintersgill was presented with the Federation's Arthur Sidney Bedell Award.

Officers for 1954–5 are as follows:

President: Alvin A. Appel, Los Angeles.

1st Vice-President: Herbert Foster, Berkeley.

2nd Vice-President: Eric V. Quartly, San Diego.

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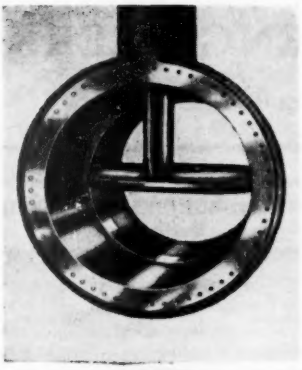

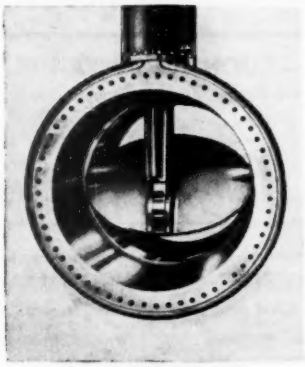

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(Continued through page 467a)

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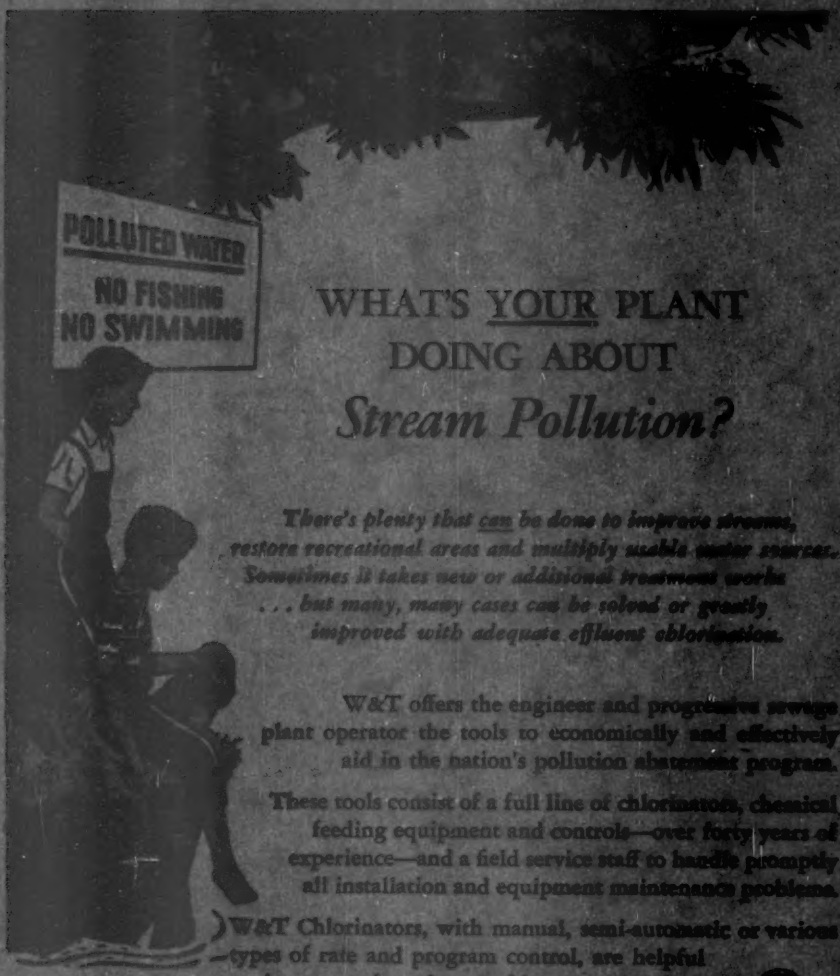

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